OHIO SOIL STUDIES. I

CHEMICAL AND MECHANICAL ANALYSES OF THE SOILS UNDER EXPERIMENT TYPES REPRESENTED DISCUSSION OF RESULTS

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 150. MAY, 1904.

OHIO SOIL STUDIES. I.

CHEMICAL AND MECHANICAL ANALYSES OF THE SOILS UNDER EXPERIMENT. TYPES REPRESENTED. DISCUSSION OF RESULTS.

BY A. D. SELBY AND JNO. W. AMES.

The results contained in the following pages are the outcome of work begun in a preliminary way several years ago; this research has been pursued because of the need to learn about the composition and behavior of the soils upon which the various and diverse experiments of the Station have been carried forward.

As to situation, the soils studied include the plots from the Station farm at Wooster and those of the Ohio State University farm at Columbus, as well as the soils of the northeastern test farm at Strongsville, Cuyahoga county, of the former northwestern test farm at Neapolis, Fulton county, of the southwestern test farm at Germantown, Miami county, and of the proposed southeastern test farm, Carpenter, Meigs county. The results thus far obtained are by no means final, but it has seemed desirable to publish an account of the progress made in the hope that the details may aid the farming public in appreciating the lack of exactness in many popular descriptive terms applied to our Ohio soils, as well as the more or less peculiar characteristics of the soils upon which the published work of the Station has been largely conducted.

The analytical work has been very largely performed by Mr. J. W. Ames, while assistant chemist, under direction of A. D. Selby, for some time chemist. All the chemical analyses of the soils of the Ohio State University Farm, Columbus, were made by Mr. F. J. Falkenbach; a large amount of preliminary work upon the Wooster soils was done by Mr. L. M. Bloomfield, both of these last named having been connected with the Station at the time the specified work was done.

In conducting such a series of analyses many problems must be worked out for the soil under examination, as is well exemplified in the weight of sample required for hydrochloric acid digestion in the soils of Wooster and Neapolis. Similar problems obtain in the matter of the mechanical analyses, and much checking of preliminary results must necessarily be made.

That work of the extent and character presented herein requires time for its completion will be readily admitted; that this period has been extended because of the limited laboratory assistance and the execution of other necessary Station investigations pursued in the chemical laboratory, should also be stated.

The methods pursued are concisely stated and the detailed results are fully published in the subsequent pages of the bulletin.

GENERAL CONSIDERATIONS.

If each technical discussion of results of investigations must always be prefaced by all the information bearing more or less directly upon the subject treated, the great length burdens all. On the other hand many limitations and specifications are to be emphasized.

In this bulletin in every instance, whether of one farm or another, the analyses given represent the composition of the soil at the time, or very near the time, the experiments were inaugurated upon the particular area. The samples for the analyses *were taken from the unfertilized plots.*

At Wooster the soil had been under cultivation for about 60 years on the East Farm and 40 years on the South Farm; at Columbus for about 50 years. As to Strongsville the land had been cleared for about 40 years and had been pastured for several years (about 20) just previous to its leasing and occupancy by the Station. At Neapolis in the oak openings, so called, the land was newly cleared about 3 to 5 years before the soil samples were taken. At Germantown the land had been cleared for 50 years and at Carpenter for 30 years. All soil samples therefore *represent as nearly as possible the condition and composition of the soils at the beginning of experimentation upon them, or as near the time of beginning as the Station had secured assistance for soil analysis.*

The influence of the cropping and fertilizing practiced upon the later soil condition and composition remains for other "studies" in the same lines to determine; nor is it the province of this paper to set forth what fertilizers should be used upon a soil of the given composition. Such matters properly belong elsewhere, particularly in the bulletins upon the maintenance of fertility, including Bulletin No. 110.

As the title indicates this is a soil study intended to be helpful as the basis for experimentation and to supply the information from which at a future time the effects of the several practices followed upon these soils may be determined by comparative examination. Such results as these should prove of both present and future value to the investigators working in this line; the sole and sufficient test of their usefulness in the end must rest upon their substantial accuracy. No reasonable effort has been spared to attain this end.

As later indicated under method of sampling, the first six inches is called SOIL; the second six inches SUBSOIL. The depth of six inches in these soils represents as nearly as may be followed by a uniform measurement over all, the depth of the soil that has been disturbed or altered by cultivation. One does not need to restate how marked is frequently the color contrast between the humus-containing soil and the subsoil on cultivated lands of the types chiefly included herein.

The senior author is much impressed by the divergence of the laboratory results from the popular descriptive terms applied to these same samples. No true "clay" soils are found on the six farms under discussion. A fuller statement of views on this subject of soil classification and the names applied to the soils in question will be found in a subsequent portion of this bulletin.

THESE SOILS CHIEFLY IN THE GLACIATED AREA.

The farms named upon which experiments have been made and soils studied are all, with the single exception of that at Carpenter, Meigs county, in the glaciated portion of Ohio. This is a fact of which the reader must properly take cognizance; it opens the way to understand the variety in the character of the pebbles found in them (see p. 87) and, with certain reservations, the essential uniformity of the samples from the same farm. No equally exhaustive examinations have been made of soils where the "country rock," that is the underlying stratum or strata, determine exclusively the soil composition and character; but two samples from Carpenter were analyzed. Yet the underlying rocks are not without influence upon these selfsame glaciated soils. The Wooster farm is underlaid by sandy shales and sandstone of the Waverly group; that of Strongsville by the Cuyahoga shale; that of Columbus rests upon the Huron shale and this in turn is underlaid by the corniferous limestone. The Germantown soil appears to be glacial till and that of Carpenter to be derived exclusively from a coal measure shale. Stratigraphically speaking, the test farm lands at Neapolis rest upon the same, or nearly the same formation as those of the University farm, Columbus, but the soil is the deep lacustrine, littoral or dune sand of what is called the fourth beach.*

These soils are very much like the sands of the present lake beach at Cedar Point, Erie county; they have their soil counterparts in the "oak openings" districts of several different counties.

While the foregoing statements of fact need to be made, too much stress might easily be placed on the particular underlying rock stratum; it would be especially easy to do this in the Germantown district and the same applies with force at Neapolis. We can conceive, without any great effort of the mind, how these shore sands of Neapolis will contain chiefly the insoluble silica, able to resist both abrasion and solution, irrespective of underlying rocks. The Strongsville soils appear to derive their character from the Cuyahoga shale, but their content in magnesia is conspicuous. This too is possibly referable to the composition of the Cuyahoga shale.

In general for Ohio, it appears that soils of the upland or plateau nature of those heretofore chosen for Station experimentation may derive their chief characteristics from the underlying strata, irrespective of whether these soils are situated within or without the glacial area of the state. It may be assumed to be otherwise with unstratified drift deposits, or field alluvial deposits, which make up a very considerable portion of the farming lands of the state. In them we may expect to find a mixed character. A little reflection would lead us to infer that the results obtained by the examination of the soils heretofore mentioned are in consonance with the conditions surrounding their formation and their subsequent history. Drainage effects from the uplands during a long forest period might

*Ohio Geology I; 549,570. Also II; 63.

be expected to remove a good deal of the material originally lying thereon, and only such as is held by the vegetation growing upon these lands will constitute the final soil of the farm.

DIFFERENTIATION OF SOIL AND SUBSOIL.

While, as already stated, of the samples taken, the first six inches in depth is called "soil," and the second six inches "subsoil," it does not follow that in every case these measurements sharply mark the differentiation of soil from subsoil. For, as is known to all practical men who have followed the plow, there is between the true soil and subsoil, outside of black lands, a sharp line of demarkation. This line of demarkation may yet vary in depth with the soil in question, the basis of the variation being found in the soil character and in the soil history. The arbitrary depth of six inches has been found fairly true to the facts in the soils examined by us. Reference to the tables giving the average results of the chemical analyses of these various soils will show a relative sameness in the insoluble matter and soluble silica; further, that there is an appreciably greater percentage of soluble mineral constituents in the subsoil at the same time that the amount of organic matter is greater in the soil than in the subsoil. It will be noted also that where the land has been in grass for some time, as in the Pomeroy tract at Strongsville, the range of difference in organic matter increases. By reference to the loss on ignition sustained by these soils, as reported in the mechanical analyses, much truer tests of the relative amounts of organic matter in soil and subsoil will be gained. The loss on ignition in the Strongsville samples of the soil is often almost double that occurring in the subsoil. While this loss is derived in part from a number of volatile compounds, such as carbonates and water in combination, a larger variation is probably to be attributed to the organic matter destroyed by ignition. At Wooster the difference is very much less, amounting on the average to less than 1 per cent. The sands of Neapolis also show suggestive differences in these regards. Attention is invited to this point. This is not the place to enter into a discussion of the various differences in the proportions of the constituents of soil and subsoil in order to trace these to their exact origin. A passing mention is all that is undertaken.

GENERAL SIMILARITY IN THE MECHANICAL CONSTITUENTS OF THE SOILS OF WOOSTER, STRONGSVILLE, GERMANTOWN AND CARPENTER.

Attention is for a time directed to the illustrations setting forth the average mechanical composition of the soils of Wooster, Strongsville, Germantown and Carpenter. If one contemplates these illustrations and tables he will note the marked similarity of these soils in the mechanical elements belonging in the group designated *silt* and *fine silt*. The same applies also to the soil of the University Farm at Columbus. There is a tendency toward comparative uniformity between these constituents in the soils and subsoils examined. These similar amounts of silt elements should lend a similarity in general behavior and in the reactions from various treatments applied in culture. Contrast for a moment this series of illustrations with those of the Neapolis soil and subsoil. Herein we find that about 85 per cent of the mechanical elements of these soils fall within the sand group and that less than 5 per cent. are found in the silts. No sharper contrast can be offered in soils than that shown between the soils of Neapolis and the soils of the other tracts examined.

The actual relative behavior of these soils under culture, leaving out of consideration those of Neapolis, will be influenced by a variety of facts; among others, first, perhaps will stand the per centage of clay. Next, possibly the amounts of sand. It is not clear just which of these will exercise the more noticeable and pervasive influence.

Possibly other features relating to the chemical constitution of the soil elements, such as the content in lime and magnesia, may influence the actual behavior of silt soils of these types. Some features indicate both a chemical and mechanical influence for magnesia. In respect to this feature attention may be directed to the relative percentages of magnesia in the various soils, particularly to the ratio between the lime and the magnesia content so conspicuously low in the Strongsville and Germantown soils. Attention is called at this time to the general similarity in the mechanical constituents of the soils of Wooster, Strongsville, Germantown and Carpenter in order that it may not be overlooked in future consideration. The other fact of the dissimilarity of the Neapolis soil will be easily and generally apprehended.

GEOLOGICAL RELATIONS OF THE SOILS ANALYZED.

WOOSTER, STATION FARM:—As already intimated, the soils of the Station lands, Wooster, of which soil examinations have been made, are situated in Wooster township, Wayne county, Ohio, and are in the nature of a rather level plateau immediately underlaid by shaly sandstones. The accompanying illustrations will convey a fairly correct idea of the appearance of these lands. The native growth, in so far as trees are concerned, consists largely of oak, chiefly white and black, hickory, several species, with an occasional chestnut on the higher lands, and with a marked undergrowth of flowering dogwood. Geologically speaking, the soils rest upon the sandy shale of the upper portion of the Waverly, known as the Logan group. (Ohio Geology, vol. VII, pages 32-33.) This shaly sandstone, or sandy shale, as we may call it, is readily broken up by atmospheric agencies and yields in large measure such mineral constituents as we find in the Wooster soils. At one point on the Station farm not far distant from the continuous crop plots (see Table VIII) a quarry was opened from the bottom of which the buff sandstone used in the construction of the Station buildings was obtained. In this quarry it was found that at the depth of about 15 feet these sandy shales were replaced by the sandstone quarried for the purpose stated.

In point of mechanical as well as chemical soil constituents our studies have convinced us of the very large part these sandy shales have played in the origin of the Wooster soils. Whatever glaciation may have done for the district as a whole it appears to have left only slight traces of the drift on these lands. These traces are marked by the percentage of granite and quartzite constituents in the coarse gravel, obtained in the preparation for the soil samples (see Table I below).

It may be further observed that it seems probable that these proportions of the comparatively resistant minerals spoken of are largely in excess of the contributions the drift materials have made to our soils.

TABLE I. Showing the proportion and character of the several kinds of soil particles LARGER THAN TWO MILLIMETERS IN DIAMETER, excepting stones, found in the first six inches of the several soils examined.*

KIND OF MINERAL	Wooster E. Farm		Wooster S. Farm		Strongsville			Columbus	Germantown	Carpenter
					Pomeroy		Blake			
	Per cent		Per cent		Per cent		Pr cent	Pr cent	Pr cent	Pr cent
Sandstone	98.12	95.16	97.02	94.60	62.52	63.01	57.56	52.79	17.88	24.10
Quartz	1.87	4.29	2.49	1.60	1.20	2.00	12.12	4.95	3.29	.35
Chert	......	37	42	......	......	......	......	19.81	4.11	......
Granite	......	27	......	3.37	1.51	3.57	1.29	......	1.32	3.55
Feldspar	......	......	......	......	......	......	......	1.83	.91	......
Unaltered shale	......	......	......	......	......	......	......	20.62	......	47.35
Bog iron ore	......	......	......	......	34.75	31.72	29.03	......	65.50	24.65
Ochre	......	......	......	......	......	......	......	......	1.10	......
Undetermined	......	......	......	......	......	......	......	......	5.83	......
Total	99.99	100.09	99.93	99.57	99.98	100.30	100.05	100.00	99.94	100.00

*Neapolis soil contains no particles larger than 2 mm.

STRONGSVILLE TEST FARM:—This farm is in Strongsville township, Cuyahoga county, O., and consists of a comparatively level area slightly broken by the erosion of streams. The original growth consisted largely of beech, sugar and oak, with an occasional tree like the chestnut marking a strong local contrast in the soil character. The soils in question are marked in general behavior by their resistance to culture save at just the right period. They are commonly known as hard, clay soils although the actual clay percentage scarcely warrants so inclusive a name. Four miles north we have the extensive quarries of the Berea sandstone belonging to the Waverly group. In the vicinity of Strongsville the soil is for the most part underlaid by one of the shales characteristic of this horizon. In the earlier geological reports we have some irregularity in the designation of this shale series. It appears we have here to do with the Cuyahoga shale; this shale was earlier designated in the Geological Report as the Waverly shale. It appears that the soils under study have derived their character from the Cuyahoga shale.

COLUMBUS:—The Ohio State University Farm, Columbus, Ohio, is situated somewhat near the meeting of the Devonian limestone and its overlying Devonian shales. For the plots in question, which are situated well back from the stream and the erosions and gravel beds that may come somewhat nearer the meeting of the limestone horizon and that of the shale, the mechanical analyses indicate a soil of the character of a loam, and one of fairly tillable constitution; the chemical analyses indicate a limestone origin of this soil, and aside from the small quantities of coarse gravel contributed by the drift it would appear that we must look here still to the underlying substratum as the chief contributor to the soil character.

GERMANTOWN TEST FARM:—With the test farm in German township, Miami county, near the village of Germantown, we have an entirely different relation to the drift. The land under discussion is situated on a somewhat marked plateau and the soil appears to be made up largely from the disintegration or change of the boulder clay. The district has an apparently more or less uniform and characteristic soil. Ditching operations disclose the same character of substratum, with very frequent boulders of granite or other erratic character. While here, as at the other points referred to, the immediately underlying stratum gives the soil character, the substratum here differs from that of the other points in being of glacial origin and not the native rock material. Mechanical analyses, however, show a close correspondence between the silt constituents of the Germantown soil and those at Strongsville. This point has already been alluded to. The chemical analyses are set forth in Table III.

CARPENTER TEST FARM:—In the case of the test farm in Columbia township, Meigs county, Ohio, near the railroad station of Carpenter, we pass within the coal measure area of Ohio. The alternating strata of coal, shale, sandstone, limestone and clay, so characteristic of the coal measure area, are all more or less familar to everyone. Naturally it follows that since this district has not been subjected to glacial action the underlying rock will be the sole factor in determining the mineral constitution of the soil. The land chosen for experimentation is of plateau character, one-half mile northeast from Carpenter, and is evidently derived from a local shale, since it is underlaid by the yellowish shale overlying the gray fossiliferous limestone known as the Ames limestone. Little need be added beyond pointing out this connection, since the elevated situation of the land insures that the soil will be wholly derived from the shale on which it rests.

NEAPOLIS TEST FARM:—We have already alluded to the situation of the soils at Neapolis. In this district we are dealing with ancient shore sands of Lake Erie. In the geological past it has been shown that a large lake, a great western extension of the modern Lake Erie, occupied the district now included in parts of northwestern Ohio and northeastern Indiana, possibly including parts of southern Michigan. With the filling of this lake by sandy and other deposits there were formed the soils of the district under discussion. At Neapolis we have this soil character—the yellowish and friable sands described in earlier geological reports as the sands of the fourth beach. A few of these are so light and fine that they are blown freely by the wind. Here, decidedly, we have the soil character entirely determined by the geological stratum which constitutes it. It would not be fair to state that the growth of plants upon these sands has wrought no change upon the sands, yet the major soil constituents are just those of the sandy lake beaches found in our day along the lake shore.

DETAILED RESULTS OF ANALYSES.

1ST, WOOSTER:—By reference to Table II it will be observed that the average of 18 plots in the various sections at Wooster, exclusive of the South Farm, gives in the mechanical analysis 25.23 per cent total sand for the soil and 24.10 per cent for the subsoil. The total silt in the soil is 65.43 per cent, in the sub-soil 64.57 per cent. The clay in the soil is 4.71 per cent, in the subsoil, 6.57 per cent. The coarse gravel, which may in fact be added to the sand for a final sand-like total, amounted on the average in these plots to 5.84 per cent for the soil and 4.62 per cent for the subsoil.

The South Farm shows in an average of four plots, 20.83 per cent total sand in the soil, and 21.94 per cent total sand in the subsoil; while the same shows in total silt, 69.55 per cent for the soil and 66.20 per cent for the subsoil.

METHODS OF ANALYSIS.

SAMPLING AND PREPARATION OF THE SAMPLE.

To obtain an average sample, portions of the soil of uniform thickness from the surface to the required depth were removed from several places in each plot. In this work, that part of the soil from the surface to a depth of 6 inches represents the soil sample, and the portion from 6 inches below the surface to a depth of 12 inches, the subsoil.

Each sample after being dried is spread out on a smooth surface, all lumps are broken up with a wooden pestle and the whole is thoroughly mixed.

CHEMICAL ANALYSIS.

500 grams of the prepared sample are sifted through a sieve with openings one half millimeter in diameter; the fine earth passing through is carefully preserved and portions of this are weighed for analysis.

WATER AND VOLATILE MATTER.

2 grams of fine earth are weighed in a platinum dish and heated in a water oven for five hours, or until a constant weight is obtained, covered with a watch glass, cooled in dessicator and weighed, keeping the dish covered. The loss in weight represents the moisture in the sample.

The dish and dry soil are heated to a full red heat until all organic matter is burned off. The loss in weight represents organic matter, combined water and volatile salts.

INSOLUBLE MATTER AND ACID SOLUBLE COMPOUNDS.

5 grams of fine earth are placed in a 200 cc. flask fitted with a stopper and condensing tube; 25 cc. hydrochloric acid, 1.115 sp. gr. are added, and digested for 10 hours in a water bath, shaking the flask frequently. The contents of the flask are filtered, the residue washed twice with hot water containing a small quantity of hydrochloric acid and finally with hot water until free from acid. A few drops of nitric acid are added to the filtrate, which is evaporated to dryness and heated in air oven to 110° until all acid is driven off. The residue is taken up with a few drops of hydrochloric acid and hot water, filtered and washed. The precipitate—soluble silica—is added to the residue from the first filtration, ignited and weighed as insoluble matter and soluble silica.

Another portion of fine earth, 15 grams, is digested with 100 cc. hydrochloric acid, sp. gr. 1.115, in the same manner as the 5 gram sample; after filtering and washing the residue is discarded. The filtrate is evaporated and treated as before, combined with the filtrate from the 5 gram sample and made up to a volume of 500 cc. Portions of this solution are taken for determination of the acid soluble compounds.

The methods followed are mainly those of the Association of Official Agricultural Chemists.

FERRIC OXID, ALUMINA AND PHOSPHORIC ACID.

To 100 cc. of the acid solution, heated to boiling, ammonium hydroxid is added until slightly alkaline. It is allowed to stand for 15 minutes, filtered and washed by decantation; the precipitate is dissolved with a few drops of hydrochloric acid and reprecipitated with ammonium hydroxid, as before. The precipitate is dried, ignited and weighed. The weight, less the weight of phosphoric acid found in a separate determination, represents the weight of Al_2O_3 and Fe_2O_3.

CALCIUM.

The filtrate and washings from the iron and alumina determination are evaporated to about 50 cc.; ammonium oxalate and ammonia are added, heating to boiling, and the precipitate is allowed to settle; the clear solution is decanted on a filter, warm dilute hydrochloric acid is poured through the filter onto the precipitate in a beaker, and the filter paper is washed free from acid; it is reprecipitated by adding a few drops ammonium oxalate and slight excess of ammonia, allowed to stand until precipitate settles, filtered, washed free from chlorids; dried, ignited and weighed as CaO.

MAGNESIUM.

The filtrate from the calcium determination with hydrochloric acid is acidified, evaporated to about 50 cc., made slightly alkaline with ammonia, acid sodium phosphate is added, then about 10 cc. ammonia and allowed to stand over night in a cold place; filtered, ignited and weighed as $Mg_2P_2O_7$.

FERRIC OXID.

100 cc. of the solution obtained from filtering the insoluble matter are evaporated with 10 cc. sulfuric acid until free from chlorids; diluted with water, reduced with zinc, and per cent of F_2O_3 determined with standard potassium permanganate solution.

PHOSPHORIC ACID.

200 cc. of the acid solution are evaporated to about 25 cc.; nearly neutralized with ammonia; 10 grams ammonium nitrate and 25 cc. molybdic solution are added and kept at temperature of 40° for several hours. The yellow precipitate of ammonium phosphomolybdate is filtered, washed with cold 1 per cent solution of ammonium nitrate and dissolved in ammonia; re-precipitated by adding nitric acid in slight excess and 5 cc. molybdic solution allowed to stand until the yellow precipitate has completely separated, filtered, washed and dissolved in ammonia as before. The excess of ammonia is neutralized with hydrochloric acid; the phosphoric acid precipitated with magnesia mixture and ignited and weighed as magnesium pyrophosphate.

SULFURIC ACID.

200 cc. of the original solution are evaporated almost to dryness. The residue is taken up with 50 cc. distilled water, heated to boiling, 5 cc. barium chlorid solution are added, allowed to stand in water bath until precipitate settles completely, filtered, washed free from chlorids, ignited and weighed as barium sulfate from which the per cent SO_3 is calculated.

POTASH AND SODA.

The filtrate from the sulfuric acid determination is made alkaline with ammonia and filtered. The filtrate is evaporated to dryness, and heated at low temperature to expel the ammonium salts, then dissolved in water and heated to boiling; 5 cc. of barium hydroxid solution are added; the whole is filtered and washed with hot water, adding ammonia and ammonium carbonate, filtering into weighed platinum dish, evaporating to dryness and heating until all ammonium salts are driven off; it is then allowed to cool and weighed as NaCl and KCl. Potassium is determined as potassium platinic chlorid. The weight of the combined chlorids, less the weight of potassium chlorid equals the sodium chlorid.

NITROGEN.

Nitrogen is determined by the Kjeldahl method modified to include nitrates.

METHODS OF MECHANICAL ANALYSIS.

200 grams of the soil sample are sifted on a sieve with circular openings 2 millimetres in diameter. The particles remaining on the sieve are washed, dried and weighed as coarse gravel, greater than 2 mm.; the portion which passes through the sieve is called "fine earth"; this is used in making the mechanical separations.

MOISTURE AND ORGANIC MATTER.

Five grams of the air dry fine earth are dried at 110° C. to nearly constant weight. After being dried the sample is ignited at low red heat until the organic matter is oxidized; it is allowed to cool and weighed. The loss in weight after ignition represents the organic matter.

MECHANICAL SEPARATION.

The method used for these analyses is Osborne's beaker method.

Twenty grams of the air dry fine earth are taken for the mechanical analysis. Before making the mechanical separations it is necessary that the particles composing the mass of the soil be thoroughly separated from each other. This is accomplished by placing 20 grams of soil in an 8 ounce sterilizer bottle, such as is used for sterilizing milk; the bottle is half filled with distilled water, closed with a rubber cork and placed in a shaking machine.

The machiue used in this laboratory consists of a box fitted with compartments for holding the bottles lying on their sides. The box is suspended from a frame work overhead by means of rods attached to the corners; it is moved back and forth at the rate of about 100 revolutions of shaft a minute. The shaking is continued for two days. The disintegrated soil is then washed into a 3 inch beaker, water added and thoroughly stirred. It is allowed to settle until all particles greater than .05 m. have subsided. This is determined by withdrawing a portion of the turbid liquid from near the bottom of the beaker: a drop is placed on a microscope slide and examined under a microscope fitted with an eye piece micrometer. When all particles larger than .05 mm. have subsided the turbid liquid containing silt, fine silt and clay is poured into a larger beaker. This operation is repeated until all particles less than .05 mm. have been removed. The sediment in the beaker is transferred to a platinum or porcelain dish, ignited and weighed as total sand. The total sand is further separated by being passed through a series of brass sieves 4 in. in diameter, which fit into each other. The first sieve has circular openings 2 mm. in diameter, the second 1 mm. and the third .5 mm. The particles passing through the lower sieve are sifted through screens of No. 5 and No. 13 bolting cloth, through which particles of .25 and .1 mm. diameter will pass. The bolting cloth is stretched on circular wooden frames which are clamped to a pan and fastened upon the shaking machine.

The turbid liquid in the second beaker is allowed to settle until a drop taken from near the bottom of the beaker shows that all particles greater than .01 mm., silt, have settled. The liquid containing fine silt and clay is then decanted to a third beaker, which should be of 2 liters or more capacity. The sediment in the bottom of the beaker is stirred up with more water, allowed to settle and decanted. This is continued until the sediment has been washed free from all particles less than .01 mm. When this is accomplished the silt is washed into a small porcelain dish, evaporated, ignited and weighed. The result will be the p r cent of silt particles larger than 05 mm. and less than .01 mm. The liquid in the third beaker contains the fine silt and clay; it is allowed to settle until everything larger than .005 mm.—fine silt—has subsided. The time required for the separation for the fine silt and clay, varies from 12 to 24 hours, depending on the character of the soil.

The sediment in the third beaker should contain no particles less than .005. mm. It is transferred to a small dish, evaporated, ignited and weighed as fine silt. The clay water containing everything less than .005 mm. is measured and an aliquot portion evaporated, ignited and weighed.

The per cent of clay in these is 4.26 for the soil, and 7.38 for the subsoil, while the coarse gravel is only 1.94 percent on the average for the soil and .66 per cent for the subsoil. It will be noted that the loss on ignition is relatively higher for the South Farm when the soil is considered and less in the subsoil than of the other Wooster soils examined. The average results are graphically shown in the diagrams which appear upon subsequent pages.

By reference to the diagrams and Table III the average chemical composition of 16 plots of soil from the East Farm and 5 plots from the South Farm and the average chemical composition of 21 plots of soil at Wooster inclusive of the South Farm are also exhibited, and in the tables of details the plot results and averages of the chemical analyses made are also shown. It will be noted that the insoluble matter and soluble silica in the Wooster soils is quite high, and that the actual soluble plant food is contained in a very small percentage of the total soil weight. The percentage of potash in the soil is about 0.25 per cent, being almost the same in soil and subsoil. It will be noted however, that on the average the South Farm plots give .10 per cent higher content of potash in the soil than does the remainder of the Station Farm. The percentage of lime in the Wooster soils is quite low, amounting to less than 3-10 of 1 per cent. The per centage of magnesia is somewhat higher than that of lime, amounting to about 4-10 of 1 per cent. The percentage of phosphoric acid, or phosphorus pentoxid, is a little more than 12-100 of 1 per cent, being higher in the South Farm than in the remainder. The ratio of lime to magnesia in average of all is about 1:1.5.

It is proposed to call this soil type of the Station Farm the Wayne silt loam.

TABLE II.—Summary of results of MECHANICAL ANALYSES of Soil and Subsoil on the Ohio Experiment Station Farm, Wooster. The Ohio State University Farm, Columbus, and the Station Test Farms at Strongsville, Neapolis, Germantown and Carpenter.

	No. analyses	Very coarse sand (2-1mm)	Coarse sand (1-.5 mm)	Medium sand (.5-.25 mm)	Fine sand (.25-.1 mm)	Very fine sand (.1-.05 mm)	Total sand	Silt (.05-.01 mm)	Fine silt (.01-.005 mm)	Total silt	Clay (<.005 mm)	Total mineral matter	Loss on ignition	Total
SOIL—First six inches.		Per ct	Per ct	Per ct	Per ct	Per ct	Pr ct	Per ct	Per ct	Pr ct	Per ct	Per ct	Per ct	Per ct
Wooster, East Farm	18	72	1 01	.83	1.93	20 81	**25.23**	25.15	40.28	**65.43**	4 60	**95.32**	3 57	99 95
Wooster, South Farm	4	.52	1.02	.74	1.42	17.07	**20.83**	27 81	41.74	**69.55**	4 26	**94.65**	4 21	100 05
Wooster, average	22	.69	1.01	.82	1 75	20 13	**23.58**	25 64	40 57	**66.21**	4 54	**95.30**	3 64	99 89
Strongsville	18	1 74	2.39	2 32	5 14	10.63	**22.23**	27 03	35.21	**62.24**	7,18	**91.64**	6 51	99 99
Columbus	2	83	2.10	2 71	7 78	17 77	**31.20**	28 29	28 22	**56.51**	6 12	**93.83**	4 69	99 68
Neapolis, (yellow sand)	3	.13	1.03	3 37	37 54	46 29	**88.36**	2 57	3 40	**5.97**	2 46	**96.80**	2 43	100 20
Neapolis, (black sand)	2	.02	81	2 81	31 52	51.59	**86.76**	2 20	2 80	**5.00**	1.22	**92.99**	5 51	99 72
Germantown	1	1 04	1 93	1.96	4 34	9 09	**18.36**	50.21	17 72	**67.93**	8 89	**95.18**	3 46	99 69
Carpenter	2	52	1 80	1 55	2.33	4 75	**10.94**	47.43	26 01	**72.44**	9 71	**94.08**	4 89	100 08
SUBSOIL—Second six inches.														
Wooster, East Farm	18	1 04	1 13	1.02	1.99	18.89	**24.10**	26.31	28.26	**64.57**	6 57	**95.80**	3 11	100 01
Wooster, South Farm	4	.40	69	.70	1 34	18.79	**21 94**	29.68	36.53	**66.21**	7 38	**95.64**	2 88	99 76
Wooster, average	22	.93	1 06	.95	1.86	18 82	**23.71**	26 92	37 94	**64.86**	6 71	**95.77**	3 07	99 97
Strongsville	18	.99	1 47	1 83	4.42	8 04	**17.25**	28 42	33 45	**61.87**	15 61	**94.61**	3 91	100 38
Columbus	2	.65	1.99	2.59	8.08	17 66	**30.98**	27 29	28 57	**55.86**	7 42	**94.27**	4 36	99 84
Neapolis, (yellow sand)	3	.31	1 33	3.00	32.78	52 11	**89.54**	2 40	2 76	**5.16**	2 39	**97.11**	1 18	99 32
Neapolis, (black sand)	2	04	.76	2 54	32.20	51 59	**87.14**	3 45	2.75	**6.20**	2.07	**95.42**	3 16	99 92
Germantown	1	1 19	1 79	1 86	4 33	12 94	**22.11**	40.96	18 43	**59.39**	14.58	**96.08**	3 12	100 38
Carpenter	2	35	1 27	1 21	1 48	3 52	**7.83**	46 50	24 62	**72.12**	16 01	**94.[illegible]3**	3 72	99 [illegible]9

TABLE III*—Summary of results of CHEMICAL ANALYSES of Soil and Subsoil on the Ohio Experiment Station Farm, Wooster, the Ohio State University Farm, Columbus, and the Station Test Farms at Strongsville, Neapolis, Germantown and Carpenter.

	No. Analyses	Insoluble matter and soluble silica	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Ferric oxid Fe_2O_3	Alumina Al_2O_3	Phosphorus pentoxid P_2O_5	Sulfur trioxid SO_3	Water and organic matter	Total	Total nitrogen
SOIL—First six inches.		Per cent	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct
Wooster (East Farm)......	16	88.73	.216	.39	.23	.39	2.67	2.79	.089	.04	4.41	100.00	.096
Wooster (South Farm)....	5	87.53	.314	.24	.21	.39	2.70	3.21	.157	.03	4.93	99.71	.091
Wooster, average.........	21	88.44	.239	.26	.26	.39	2.68	2.88	.105	.03	4.52	99.81	.093
Strongsville............	13	83.58	.235	.29	.22	.46	3.24	3.27	.127	.05	8.31	99.75	.187
Columbus................	8	83.44	.561	.74	.53	.62	3.41	4.85	.142	.09	5.86	100.28	.249
Neapolis (yellow sand)....	2	93.21	.053	.06	.19	.12	.99	.99	.125	.03	3.95	99.73	.091
Neapolis (black sand).....	2	[illegible]	.050	.09	.20	.13	.67	[illegible]	.135	.03	7.17	99.75	.120
Germantown.............	1	90.55	.142	.21	.11	.31	1.68	3.17	.102	.03	3.70	100.00	.090
Carpenter................	2	85.73	.137	.11	.18	.30	2.73	3.99	.112	.03	6.89	100.26	.138
SUBSOIL—Second six inches.													
Wooster (East Farm)....	16	87.[illegible]7	.243	.38	.27	.37	3.32	3.41	.098	.04	4.11	100.11	.061
Wooster (South Farm)....	5	87.67	.225	.28	.20	.45	3.26	3.56	.144	.03	4.02	99.88	.060
Wooster, average.........	21	87.85	.2[illegible]0	.34	.25	.39	3.30	3.46	.109	.04	4.09	100.08	.061
Strongsville..............	13	83.80	.215	.29	.18	.45	4.72	4.11	.091	.03	5.92	99.81	.074
Columbus...............	8	83.87	.559	.73	.69	.62	3.63	4.26	.150	.10	5.64	100.30	.135
Neapolis (yellow sand)....	2	94.31	.065	.07	.14	.13	.82	1.97	.115	.02	2.29	99.93	.037
Neapolis (black sand).....	2	93.18	.060	.09	.24	.14	1.12	1.34	.110	.01	3.78	100.07	.113
Germantown.............	1	89.20	.210	.23	.13	.37	2.26	3.69	.115	.03	3.86	100.10	.090
Carpenter................	2	84.75	.255	.12	.15	.37	3.47	4.87	.084	.03	5.58	99.68	.070

*For a statement of the results of these chemical analyses in terms of the chemical elements involved see a subsequent table.

2ND, COLUMBUS:—The number of mechanical analyses from Columbus soil is relatively small as compared with those made for Wooster, Strongsville and Neapolis. For this reason it is sufficient to cite the total sand as amounting to 31.2 per cent in the soil and 30.98 in the subsoil; and the total silt 56:51 in the soil to 55.86 in the subsoil; while the percentages of clay are 6.12 per cent in the soil and 7.42 per cent in the subsoil.

From the standpoint of chemical composition it is to be observed that there is almost double the soluble soil constituents in the Columbus soil as compared with that found at Wooster. In this connection it will be seen also that the percentage of potash is more than double, while the other constituents, such as lime and magnesia, are increased in a slightly smaller proportion. The ratio of lime to magnesia is 1:1.007 showing the close relation of the soil to the limestone in this respect. The diagrams will bring this out even more conspicuously. While this is true of the constituents just mentioned, the phosphoric acid found in the Columbus soils in this series of plots is but little if any greater in quantity than that found at Wooster.

Taking the percentages of total sand and coarse gravel in the Columbus soils into consideration, it will be seen how much these must influence the mechanical or general working condition of this soil.

The extent of this soil type is not known to the authors. The chemical composition as well as the cultural behavior seems to mark it as distinct from that of Germantown and the Miami Valley; similar soils, though exhibiting locally less of the loamy character, are known to have considerable extent. The Olentangy silt loam is suggested as a name for the soil type.

3RD, STRONGSVILLE:—By referring to Table II one will find the average of the mechanical analyses of samples from 18 plots at the Strongsville test farm; also in the other tables the average analyses of 12 plots in the Pomeroy tract and 6 plots in the Blake portion of the same lands. Table III also gives average results of 13 chemical analyses in the two portions of the Strongsville lands. These disclose that, as to mechanical components, the Strongsville soil contains 22.23 per cent total sand, while the subsoil contains only 17.25 per cent. These selfsame soils give 62.24 per cent silt, while the subsoil contains practically the same amount, 61.87 per cent. In clay the soil yields 7.2 per cent clay against 15.6 per cent in the subsoil. The coarse gravel amounts to 3.66 per cent in the soil and less, or 2.98 per cent, in the subsoil. The loss on ignition is very high in these soils, amounting to 6.51 per cent, as a result, perhaps, of their having been some years in sod.

The chemical analyses give 83.58 per cent insoluble matter and soluble silica in the soil and the same amount, approximately, in the subsoil. Here the insoluble matter and soluble silica is quite a little less than at Wooster, while practically the same in amount as that found at Columbus. The potash found is less than at Wooster, 0.205 per cent, and less than half that at Columbus. The lime content is even less than at Wooster, only 0.22 per cent, while that of magnesia amounts to 0.46 per cent, and the ratio of lime to magnesia becomes 1:2.09. This is certainly a most anomalous fact! Notable percentages of iron oxide and alumina are also found, approximating quite closely to the corresponding percentages at Wooster, while falling below those at Columbus. The phosphorus pentoxide, (phosphoric acid), amounts to a little more than at Wooster, 0.13 per cent, almost the same as found at Columbus.

The water and organic matter give high percentages as already indicated, probably due to the prolonged sod condition of the soil previous to the beginning of experiments. The total nitrogen in this case amounts to 0.19 per cent and is quite high for the same apparent reason. If we look to the subsoil as compared with the soil, no conspicuous differences in chemical composition are especially noticeable. It may be remarked that despite the unsatisfactory behavior and unproductive original character of the Strongsville soils, the soluble portion of the soil, leaving out the volatile matter, is almost double that of Wooster and approximately the same as that of Columbus. There certainly appears to be a fine field for soil investigations in Ohio to discover the actual reasons back of the unsatisfactory behavior of the soils of Strongsville and ascertain and apply the corrective. When this is found it must further have a wide application in northeastern Ohio.

We propose the name of Cuyahoga silt for this soil type, which is characterized by a certain plastic character and may have a rather wide extent, even though not strictly co-extensive with the widespread Cuyahoga shale from which it takes origin and from which the name is likewise taken.

4TH, NEAPOLIS:—As might be expected in the drift sands of the lake shore, these soils contain of mechanical elements about 88 per cent sand; strictly 87.72 per cent for the soil and 88.78 per cent for the subsoil. In this respect it will be noted that the yellow sand is somewhat higher in the total sand percentages than the black sand, while a sample of yellow drift sand, No. 1808, gave 93.36 total sand, with practically the same composition of the subsoil. The other mechanical elements are not conspicuous, amounting to but 5.17 per cent total silt, although the clay percentage, 1.92, is rather unexpected. The coarse gravel is nothing. The average loss on ignition is not large, amounting to 3.21 per cent in soil against 1.70 per cent in the subsoil, while this ignition loss is but 0.95 per cent in the soil of the drift sand and 0.36 per cent in the subsoil of the same.

The chemical analyses show even higher per centages of insoluble matter and soluble silica than found at Wooster, amounting to 91.17 per cent in the soil and 93.75 per cent in the same number of subsoil. The lime is on the average 0.24 per cent and the magnesia 0.13 per cent in the soil, giving the ratio of lime to magnesia, approximately, 2:1. The amount of phosphorus pentoxid, (phosphoric acid) is unexpectedly high, being 0.13 per cent in the soil. In respect to phosphoric acid content the soils at Neapolis show as high percentage as any of those of which chemical examinations have been made, and higher than at Wooster. Potash is low, only $^5/_{100}$ of 1 per cent. Here it is the phosphoric acid contained in the soil which stands out conspicuously in a secondary sense; the same may be stated of the lime; it is approximately equal to that found at Wooster and Strongsville.

5TH, GERMANTOWN:—We have already alluded to the silt character of the Germantown soil. This is shown in the mechanical analyses of the soil and subsoil in question, which has been included by Dorsey and Coffey[1] in the "Miami clay loam," yet which seems to be even more properly called here the Germantown silt, yielding as it does in the soil, 18.36 per cent of total sand, 67.93 per cent of total silt and, in our sample, about 9 per cent of clay.

The chemical analyses bring out the differences between this soil and that of Strongsville, which in our test farm work may be regarded as somewhat allied in physical behavior. Potash, lime, magnesia and phosphoric acid are all very low, while the insoluble matter and soluble silica is quite high, 90.5 per cent. Possibly the least expected is the very low lime content, only 0.11 per cent in the soil and .13 per cent in the subsoil, with a lime-magnesia ratio of 1:2.8 and of 1:2.9 in soil and subsoil respectively. The deep-lying limestone strata of this area have apparently given little chemical character to this test farm soil.

*Report Field Operations, Division of Soils, U. S. D. A., 1900 97-100-Map 2.

6TH, CARPENTER:—The soils at Carpenter are upland in character, being derived from certain coal measure shales as before explained. The mechanical analyses show a pronounced "silt clay" with 10.94 per cent total sand, 73.44 per cent total silt and 9.71 per cent clay in the soil; the subsoil gives much less sand, slightly less silt and a high per centage of clay, 16.01 per cent.

In chemical composition the Carpenter soil is low in potash, 0 19 per cent, and especially low in lime, 0.18 per cent, with a lime-magnesia ratio of 1:1.75; in the subsoil this ratio becomes 1:2.6, having there less lime and more magnesia.

It is proposed to call this soil type the Meigs silt clay, since it will include quite a range of soils derived like this from the yellow shale immediately overlying the Ames limestone.

DETAILED RESULTS OF ANALYSES.

In the following tables will be found the results of the mechanical and chemical analyses of samples from the several specified unfertilized plots, situated on the respective lots of land under examination. The mechanical and chemical results for particular areas are set upon pages facing each other to facilitate ininspection.

TABLE IV—Results of MECHANICAL ANALYSES of soil and subsoil of 6 unfertilized plots of the Station, East Farm, Wooster: West Tier, Rotation, Sections A and B.

SECTION AND PLOT	SECTION A			SECTION B			
	PLOT 1	PLOT 16	PLOT 28	PLOT 1	PLOT 16	PLOT 28	
SOIL							
Sample No.	**840**	**844**	**848**	**830**	**834**	**838**	Average
Very coarse sand (2-1 mm)	.45	.56	.53	.38	.51	1.27	.62
Coarse sand (1-.5 mm)	.49	.97	.86	.91	1.10	1.50	.97
Medium sand (.5-.25 mm)	.81	.71	.84	.69	.93	1.38	89
Fine sand (.25-.1 mm)	1.47	1.51	1.54	1 20	1.53	2 50	1 62
Very fine sand (.1-.05 mm)	25.06	20.05	21.54	16.65	22 73	24.93	21 83
Total sand	**28.28**	**23.80**	**25.31**	**19.83**	**26.80**	**31 58**	**25 93**
Silt (.05-.01 mm)	21.92	22.87	23 17	27 45	22.91	22.38	23 45
Fine silt (.01-.005 mm)	41 01	44 73	41 83	42.37	40 36	37.48	41 29
Total silt	**62 93**	**67.60**	**65.00**	**69 82**	**63.27**	**59.86**	**64 74**
Clay (.005-.0001 mm)	4.77	4.20	4 03	5.91	4.62	3 40	4 50
Total mineral matter	**95.98**	**95.60**	**94.34**	**95.56**	**94.69**	**94.84**	**95 17**
Moisture, loss at 100° C	.95	.89	1.21	1 21	1.02	1.13	1 07
Loss on ignition	3.26	3 62	3.50	3.55	3.38	3.94	3.51
Total	100.19	100 11	99.05	100.32	99.09	99 91	99 73
Coarse gravel > 2 mm.	......	......	3.30	.20	1.08	9 32	3 47
Fine earth	......	......	96.70	99 80	98.92	90 68	96 52
SUBSOIL							
Sample No.	**841**	**845**	**849**	**831**	**835**	**839**	Average
Very coarse sand (2-1 mm)	.55	.50	.47	.32	.65	1.94	.74
Coarse sand (1-.5 mm)	.48	.41	.65	.57	.89	1.43	.74
Medium sand (.5-.25 mm)	1 85	.81	.97	.73	.96	1.59	1 15
Fine sand (.25-.1 mm)	1.79	1.66	1 74	1 02	1 59	2.93	1.79
Very fine sand (.1-.05 mm)	24.34	18.40	19.31	12 85	19.86	24 92	19 94
Total sand	**29 01**	**21.78**	**23.14**	**15 49**	**23.95**	**32.81**	**24 36**
Silt (.05-.01 mm)	22.68	25.63	23 62	26 07	23 27	21 49	23 89
Fine silt (.01-.005 mm)	37.30	42.38	41.34	45.61	39 47	34.95	40 17
Total silt	**59 98**	**68.01**	**64.96**	**72.28**	**62.74**	**56 44**	**64 06**
Clay (.005-.0001 mm)	7.18	6.06	6 88	7 53	9.00	6 28	7.15
Total mineral matter	**96.17**	**95.85**	**94.98**	**95 30**	**95 60**	**95 53**	**95 59**
Moisture, loss at 100° C	1.22	1.15	1.53	1.31	1 02	.97	1 20
Loss on ignition	2.45	3.07	2.86	3 80	3.53	2.84	3.0[illegible]
Total	99.84	100.07	99 87	100.41	100 24	99 34	99.88
Coarse gravel > 2 mm	......	......	1 08	1 05	3 30	17 78	5.80
Fine earth	.....	......	98.92	98.95	96.7	82.22	94.20

TABLE V—Results of CHEMICAL ANALYSES of soil and subsoil of 4 unfertilized plots of the Station East Farm, Wooster: West Tier, Rotation, Sections A and B.

SECTION AND PLOT	SECTION A		SECTION B		
	PLOT 1	PLOT 16	PLOT 1	PLOT 16	
			SOIL		
Sample No	**840**	**844**	**830**	**834**	Average
Insoluble matter / Soluble silica	89.60	89.05	87.65	87.98	88.57
Potash (K_2O)	.25	.24	.20	.28	.24
Soda (Na_2O)	.20	.52	.29	.44	.36
Lime (Ca O)	.35	.30	.27	.29	.30
Magnesia (Mg O)	.30	.43	.48	28	.37
Ferric oxid ($Fe_2 O_3$) / Alumina ($Al_2 O_3$)	5.56	5 32	6.50	6.65	6.01
Phosphorus pentoxid ($P_2 O_5$)	.07	.081	.08	.08	.078
Sulfur trioxid ($S O_3$)	.04	.03	.03	.06	.04
Water and organic matter	4 13	4.33	4.85	4 55	4 46
Total	100.60	100 30	100.35	100.61	100.46
Carbon	.938		.834		.886
			SUBSOIL		
Sample No	**841**	**845**	**831**	**835**	Average
Insoluble matter / Soluble silica	87.30	87.50	86.70	87.41	87.23
Potash ($K_2 O$)	.28	.31	.29	.50	.345
Soda ($Na_2 O$)	.20	.50	.30	.39	.347
Lime (Ca O)	.35	.33	.26	.27	.302
Magnesia (Mg O)	.29	.34	.37	.38	.34
Ferric oxid ($Fe_2 O_3$) / Alumina ($Al_2 O_3$)	8.10	7.30	8 08	7 47	7.73
Phosphorus pentoxid $P_2 O_5$)	.072	.09	.07	.081	.078
Sulfur trioxid ($S O_3$)	.06	.02	.01	.05	.04
Water and organic matter	3 92	3 96	4.58	4 06	4.13
Total	100 57	100 35	100 69	100 61	100.55
Carbon	.349		.335		.3421

TABLE VI—Results of MECHANICAL ANALYSES of soil and subsoil of 9 unfertilized plots of the Station East Farm, Wooster; East Tier, Rotation, Sections C, D and E.

SECTION AND PLOT	SECTION C			SECTION D			SECTION E			
	PLOT 1	PLOT 16	PLOT 28	PLOT 1	PLOT 16	PLOT 28	PLOT 1	PLOT 16	PLOT 28	
SOIL										
Sample No.	**800**	**804**	**808**	**810**	**814**	**818**	**820**	**824**	**828**	Average
Very coarse sand (2-1 mm)	1.26	.37	1.01	.22	.388	1.06	.37	.45	2 07	.80
Coarse sand (1-.5 mm)	1 30	.61	1.29	.69	819	1 18	61	.92	1 88	1 03
Medium sand (.5-.25 mm)	.78	.66	1.12	.75	.643	95	.54	.69	1 38	84
Fine sand (.25-.1 mm)	1 26	2.06	2 51	2.24	1.57	1.67	1 46	1.60	2.84	1.91
Very fine sand (.1-.05 mm)	19.74	20 21	17.94	20 89	21 03	20 89	17 53	17 90	26 05	20.24
Total sand	**24.34**	**23.91**	**23 87**	**24.79**	**24 45**	**25 75**	**20 51**	**21 56**	**34 22**	**24 82**
Silt (.05-.01 mm)	31 81	31.68	23 20	30 90	26 48	22 08	26 79	25 94	24.36	27 03
Fine silt (.01-.005 mm)	34 71	34 37	41.29	35 02	40 17	41 77	43 75	42 69	33 85	38.62
Total silt	**66 52**	**66 05**	**64.49**	**65 92**	**66 65**	**63 85**	**70 54**	**68 63**	**58.21**	**65.65**
Clay (.005-.0001 mm)	4.81	5 11	6 21	4.47	3.69	4.68	4 97	5 68	3.27	4 76
Total mineral matter	**95.67**	**95.07**	**94 57**	**95.18**	**94 79**	**94 28**	**96 02**	**95 87**	**95 70**	**95 24**
Moisture, loss at 100° C.	1 15	.73	1 14	.88	.65	1 00	1 20	1.15	.85	97
Loss on ignition	3 46	3.90	3 92	3.47	4 08	4.93	2 86	3 51	3 21	3 70
Total	100 28	99.70	99.63	99 53	99 52	100.21	100 08	100.53	99.76	99.92
Coarse gravel > 2 mm	2.14	5 55	3.70	4 81	1 81	8.45	.....	......	23 97	7.24
Fine earth	97 86	94.45	96 30	95.19	98.19	91 55	......	......	76.03	92 79
SUBSOIL										
Sample No	**801**	**805**	**809**	**811**	**815**	**819**	**821**	**825**	**829**	Average
Very coarse sand (2-1 mm)	.896	1.92	69	1.73	.56	.66	1 00	1.15	2.86	1 27
Coarse sand (1-.5 mm)	1.185	1.77	87	1 86	1.14	1 02	1.21	1.30	1.76	1.35
Medium sand (.5-.25 mm)	.79	1.13	.86	1 15	.65	99	.75	.80	1.42	.95
Fine sand (.25-.1 mm)	1.82	2.74	1.68	3.06	1.80	1.78	1.78	1.70	2.83	2.13
Very fine sand (.1-.05 mm)	15 35	17.28	14.17	18 85	15 75	15 57	16.92	17.22	23 92	17.22
Total sand	**20.03**	**24 84**	**18.27**	**26 65**	**19.90**	**20.02**	**21.66**	**22 17**	**32.79**	**22 91**
Silt (.05-.01 mm)	34 08	29 69	27.69	31.20	34 86	25 31	25.57	26 08	22.40	28 54
Fine silt (.01-.005 mm)	35.05	33.67	43.18	32.56	35 44	43 37	39 96	37 97	33.85	37 22
Total silt	**69.13**	**63.36**	**70.87**	**63 76**	**70.30**	**68 63**	**65.53**	**64 05**	**56 25**	**65 75**
Clay (.005-.0001 mm)	5.97	7.43	6.48	5.97	4 94	7.04	9.02	10 00	7 44	7 14
Total mineral matter	**95.13**	**95.63**	**95.62**	**96 38**	**95.14**	**95.74**	**96.21**	**96.22**	**96.46**	**95.81**
Moisture, loss at 100° C.	1.14	1.22	1.31	.92	1 04	1.21	.96	1 01	1.00	1.09
Loss on ignition	2.98	3.52	2.76	3.41	3.70	3.15	3 16	2.87	2 60	3.14
Total	99.25	100.37	99.69	100.71	99.88	100.10	100.33	100.10	100.06	100.04
Coarse gravel > 2 mm	4.54	4.65	3.02	4 60	.49	2.33	.....	......	40.33	8.57
Fine earth	95.47	95.35	96.98	95.40	99.51	97.67	......	.....	59.67	91.43

TABLE VII—Results of CHEMICAL ANALYSES of soil and subsoil of 6 unfertilized plots of the Station East Farm, Wooster: East Tier, Rotation, Sections C, D and E.

SECTION AND PLOT	SECTION C		SECTION D		SECTION E		
	PLOT 1	PLOT 16	PLOT 1	PLOT 16	PLOT 1	PLOT 16	
SOIL							
Sample No.	800	804	810	814	820	824	Average
Insoluble matter / Soluble silica	89.67	88.70	87.78	88.45	88.49	88.26	88.56
Potash (K_2O)	.15	.15	.16	.14	.16	.19	.16
Soda (Na_2O)	.50	.51	.41	.45	.35	.14	.39
Lime ($Ca\ O$)	.21	.25	.37	.23	.25	.33	.27
Magnesia ($Mg\ O$)	.43	.43	.42	.42	.40	.40	.42
Ferric oxid ($Fe_2\ O_3$)	2.35	2.92	2.66	2.88	2.50	2.88	2.70
Alumina ($Al_2\ O_3$)	1.94	2.37	3.29	2.77	2.97	2.59	2.65
Phosphorus pentoxid ($P_2\ O_5$)	.064	.091	.101	.089	.11	.129	.098
Sulfur trioxid ($S\ O_3$)	.04	.07	.04	.032	.037	.032	.042
Water and organic matter	4.40	4.54	4.42	4.69	4.78	4.61	4.57
Total	99.75	100.03	99.65	100.152	100.047	99.56	99.86
Carbon	1.157			1.188			1.173
SUBSOIL							
Sample No.	801	805	811	815	821	825	Average
Insoluble matter / Soluble silica	89.67	87.76	88.76	88.72	87.63	88.06	88.00
Potash ($K_2\ O$)	.14	.20	.20	.11	.13	.17	.158
Soda ($Na_2\ O$)	.42	.52	51	.32	.38	.28	.405
Lime ($Ca\ O$)	.24	.26	.31	.22	.26	.30	.265
Magnesia ($Mg\ O$)	.42	.40	.43	.40	.39	.43	.41
Ferric oxid ($Fe_2\ O_3$)	3.07	3.23	3.59	2.66	2.92	3.17	3.11
Alumina ($Al_2\ O_3$)	3.21	3.84	3.43	2.87	3.56	3.04	3.33
Phosphorus pentoxid ($P_2\ O_5$)	.08	.101	.033	.131	.14	.107	.107
Sulfur trioxid ($S\ O_3$)	.05	.06	.05	.037	.032	.042	.045
Water and organic matter	3.52	3.45	3.97	4.19	3.98	4.41	3.92
Total	100.22	99.82	99.33	99.66	99.42	100.01	99.74
Carbon	.75			.779			.764

TABLE VIII—Results of MECHANICAL ANALYSES of soil and subsoil of 3 unfertilized plots of the Station, East Farm, Wooster: West Tier, Sections of continuous Wheat, Oats and Corn.

SECTION AND PLOT	Section of continuous wheat PLOT 1	Section of continuous oats PLOT 1	Section of continuous corn PLOT 7	
SOIL				
Sample No	850	854	860	Average
Very coarse sand (2-1 mm)	.65	.70	.76	.70
Coarse sand (1- 5 mm)	1 27	.76	1.03	1.02
Medium sand (5- 25 mm)	.82	.90	.77	.83
Fine sand (.25- 1 mm)	1 93	1.90	2.29	2.04
Very fine sand (.1-.05 mm)	21 07	18.69	21.66	20.47
Total sand	**25 74**	**22.95**	**26 51**	**25.06**
Silt (.05-.01 mm)	23.18	24.43	21.22	22.94
Fine silt (01-.005 mm)	42.44	44.25	43.29	43.33
Total silt	**65.62**	**68.68**	**64.51**	**66.27**
Clay (.005-.0001 mm)	5.01	4.08	4.86	4.65
Total mineral matter	**96.37**	**95 71**	**95.88**	**95.98**
Moisture, loss at 100° C	1.02	.84	.74	.86
Loss on ignition	3.58	3.92	3.13	3.54
Total	100.97	100.47	99.75	100.38
SUBSOIL				
Sample No	851	855	861	Average
Very coarse sand (2-1 mm)	.77	81	1.33	.97
Coarse sand (1-.5 mm)	1.43	.95	1.33	1.23
Medium sand (5- 25 mm)	.92	.91	1.04	.95
Fine sand (25- 1 mm)	2 31	1.91	2.53	2.25
Very fine sand (.1-.05 mm)	21.72	17.39	25.98	21.69
Total sand	**27.15**	**21.97**	**32.21**	**27.10**
Silt (.05-.01 mm)	24.11	26.91	22.38	24.47
Fine silt (01-.005 mm)	38 28	40.73	33.63	37.56
Total silt	**62 39**	**67.64**	**56.01**	**62.03**
Clay (.005-.0001 mm)	6.52	6.51	7.93	6.98
Total mineral matter	**96.06**	**96.12**	**96.15**	**96.10**
Moisture, loss at 100° C.	1.11	.98	.87	.986
Loss on ignition	2.90	3.17	3.13	3.06
Total	100.07	100.27	100.15	100.16

TABLE IX—Results of CHEMICAL ANALYSES of soil and subsoil of 6 unfertilized plots of the Station East Farm, Wooster: West Tier, Sections of continuous Wheat, Oats and Corn.

SECTION AND PLOT	Section of continuous wheat		Section of continuous oats		Section of continuous corn		
	PLOT 1	PLOT 7	PLOT 1	PLOT 7	PLOT 1	PLOT 7	
SOIL							
Sample No	850	852	854	856	858	860	Average
Insoluble matter / Soluble silica	88.70	89.22	88 50	89.22	88.45	89.98	9.01
Potash (K_2O)	.29	.27	.25	.24	.20	.28	.26
Soda (Na_2O)	.23	.50	.52	.52	.38	.22	.39
Lime (CaO)	.32	.20	.24	.28	.25	.30	.26
Magnesia (MgO)	.23	.35	.44	.37	.43	.36	.36
Manganese oxid (MnO)							
Ferric oxid (Fe_2O_3)	5.90	2.40	6 32	2.43	2 44	2.39	2 41 (5.51)
Alumina (Al_2O_3)		2.82		2 53	3.22	2.62	2.79
Phosphorus pentoxid (P_2O_5)	.07	.079	.08	.097	.118	.08	.087
Sulfur trioxid (SO_3)	.03	.03	.04	.04	.02	.02	.03
Water and organic matter	4.60	4 15	4.51	4 02	4.54	3·45	4.21
Total	100.37	100.03	100.90	99.74	100.01	99.70	100.12
Total nitrogen	.100		.092		.096		.096
Carbon	1.120			.96		.667	.915
SUBSOIL							
Sample No	851	853	855	857	859	861	Average
Insoluble matter / Soluble silica	87.66	89.25	88 60	88.97	86.83	87.65	88.16
Potash (K_2O)	.32	.20	.36	.24	.27	.22	.27
Soda (Na_2O)	.24	.40	.55	.42	.29	.29	.36
Lime (CaO)	.19	.27	.26	.30	.22	.20	.24
Magnesia (MgO)	.18	.45	.31	.39	.51	.36	.37
Manganese oxid (MnO)							
Ferric oxid (Fe_2O_3)	(7.42)	3.26	6.00	2 83	3.49	2 96	3.09 (6.36)
Alumina (Al_2O_3)		2 42		2.99	4 11	2 62	3 03
Phosphorus pentoxid (P_2O_5)	.08	.129	.07	.139	.095	.099	.104
Sulfur trioxid (SO_3)	.04	.03	.05	.03	.02	02	.03
Water and organic matter	4 20	3 37	4.60	3 51	4 42	5.59	4.28
Total	100.33	99 77	100.80	99 81	100.25	100 00	100 16
Total nitrogen	.059		.073		.059		.063
Carbon	.495			550		.506	.517

TABLE X.—Results of MECHANICAL ANALYSES of soil and subsoil of 4 unfertilized plots of Station South Farm, Wooster: Potato Rotation, Sections A and C.

SECTION AND PLOT.	SECTION A		SECTION C		
	PLOT 13	PLOT 31	PLOT 4	PLOT 31	
SOIL					
Sample No	872	876	862	868	Average
Very coarse sand	.21	.52	.71	.88	.58
Coarse sand (1-.5 mm)	.68	1.18	.70	1.53	1.02
Medium sand (.5-.25 mm)	.59	.71	.68	1.00	.74
Fine sand (.25-.1 mm)	1.36	.63	1.82	1.87	1.42
Very fine sand (.1-.05 mm)	17.12	17.26	17.70	16.19	17.07
Total sand	**19.96**	**20.30**	**21.61**	**21.47**	**20.84**
Silt (.05-.01 mm)	34.95	26.88	22.97	26.44	27.81
Fine silt (.05-.005 mm)	35.97	44.81	44.93	41.26	41.71
Total silt	**70.94**	**71.69**	**67.90**	**67.70**	**69.55**
Clay (.005-.0001 mm)	4.01	2.93	5.01	5.10	4.26
Total mineral matter	**94.89**	**94.92**	**94.52**	**94.27**	**94.65**
Moisture, loss at 100° C	1.05	1.20	1.21	1.31	1.19
Loss on ignition	3.45	4.07	4.39	4.94	4.21
Total	98.39	100.19	100.12	100.52	100.05
Coarse gravel > 2 mm	1.91	.31	......	3.62	1.94
Fine earth	98.09	99.69	......	96.38	98.05
SUBSOIL					
Sample No	873	877	863	869	Average
Very coarse sand	.17	.03	.52	.89	.40
Coarse sand (1-.5 mm)	.50	.49	.66	1.14	.698
Medium sand (.5-.25 mm)	.50	.51	.80	1.00	.70
Fine sand (.25-.1 mm)	1.00	1.10	1.85	1.43	1.34
Very fine sand (.1-.05 mm)	21.16	19.53	19.29	15.20	18.79
Total sand	**23.33**	**21.66**	**23.12**	**19.66**	**21.93**
Silt (.05-.01 mm)	32.11	32.48	25.89	28.27	29.68
Fine silt (.01-.005 mm)	32.37	32.47	41.16	40.11	36.53
Total silt	**64.48**	**64.95**	**67.05**	**68.38**	**66.21**
Clay (.005-.0001 mm)	7.98	8.20	5.78	7.57	7.38
Total mineral matter	**95.79**	**94.81**	**95.95**	**95.61**	**95.54**
Moisture, loss at 100° C	1.25	1.44	1.03	1.20	1.23
Loss on ignition	3.04	3.05	2.54	2.90	2.88
Total	100.08	99.30	99.52	99.71	99.76
Coarse gravel > 2 mm	.61	1.23	......	2.57	1.57
Fine earth	99.39	98.77	......	97.43	98.53

TABLE XI.—Results of CHEMICAL ANALYSES of soil and subsoil of 5 unfertilized plots of Station South Farm, Wooster; Potato Rotation, Sections A and C.

SECTION AND PLOT	SECTION A		SECTION C			
	PLOT 13	PLOT 31	PLOT 4	PLOT 22	PLOT 31	
SOIL						
Section No	**872**	**876**	**862**	**866**	**858**	Ave.
Insoluble matter / Soluble silica	87.28	88.53	87.59	87 85	86 38	87 536
Potash (K_2O)	**.28**	**.27**	**.39**	**.29**	**34**	**.314**
Soda (Na_2O)	.20	.26	.25	.22	.27	21
Lime (Ca O)	**.225**	**.187**	**.24**	**.20**	**202**	.21
Magnesia (Mg O)	.368	.375	.45	.39	.358	.3882
Manganese oxid (Mn O)						
Ferric oxid (Fe_2O_3)	3 04	2 43	3 19	2.24	2 58	2 696
Alumina (Al_2O_3)	3.16	2.90	3.59	2 82	3.58	3 21
Phosphorus pentoxid (P_2O_5)	**.151**	**.118**	**.167**	**.191**	**.156**	**.157**
Sulfur trioxid (SO_3)	.021	.024	.031	.042	.047	.033
Water and organic matter	4.72	4.28	3.68	5.48	6 49	4 93
Total	99.43	99.37	99.57	99.72	100.40	99 702
Total nitrogen	.112	.084	.097			.0914
Carbon	.949			1.531		1 24
SUBSOIL						
Sample No	**873**	**877**	**863**	**867**	**859**	Ave.
Insoluble matter / Soluble silica	88.23	86.31	88 19	89.16	86.48	87 07
Potash (K_2O)	**.25**	**.31**	**.30**	**.23**	**.22**	**.26**
Soda (Na_2O)	.29	.23	.20	.31	.37	.28
Lime (Ca O)	**.177**	**.287**	**.19**	**.19**	**.18**	**.20**
Magnesia (Ng O)	.51	.464	.42	.39	.445	.45
Manganese oxid (Mn O)						
Ferric oxid (Fe_2O_3)	3.57	3.64	2 85	2 81	3 42	3.26
Alumina Al_2O_3	3 31	4 00	3 42	3 27	3 80	3.56
Phosphorus pentoxid (P_2O_5)	**.126**	**.134**	**.148**	**.151**	**.161**	**.144**
Sulfur trioxid (SO_3)	.026	.026	.025	.039	.029	.029
Water and organic matter	3.76	4.10	4.11	3 65	4.51	4.02
Total	100 25	99.50	99.85	100.10	99.62	99.88
Total nitrogen	.089	.070	.048	.041		.0596
Carbon	.475			.53		.503

TABLE XII.—Results of MECHANICAL ANALYSES of soil and subsoil of 2 unfertilized plots of Ohio State University Farm, Columbus, O. Continuous Wheat Section.

	SOIL			SUBSOIL		
Sample No	1890	1892	Average	1891	1893	Average
Very coarse sand	694	97	832	.583	.72	.65
Coarse sand (1-.5 mm)	1 72	2 48	2.10	1 62	2.36	1 99
Medium sand (.5-.25 mm)	2 21	3 22	2.71	2 398	2.79	2 594
Fine sand (.25-.1 mm)	6 99	8.57	7 784	7 425	8 74	8 083
Very fine sand (.1-.05 mm)	17 34	18 20	17 77	17 321	18 00	17 66
Total sand	**28.97**	**33.44**	**31.20**	**29.35**	**32.61**	**30.98**
Silt (.95-.01 mm)	30 65	25 94	28.29	28 96	25 63	27.29
Fine silt (.014:005 mm)	28 56	27 89	28 22	28 79	28 35	28 57
Total silt	**58.21**	**53.83**	**56.51**	**57.75**	**53.98**	**55.86**
Clay (.005-.0001 mm)	5 38	6 85	6 115	6 47	8 37	7 42
Total mineral matter	**93.56**	**94.12**	**93.83**	**93.57**	**94.96**	**94.26**
Moisture, loss at 100° C	1 15	1 07	1 11	1.21	1.23	1.22
Loss on ignition	5 25	4 12	4 69	4 69	4 03	4 36
Total	99 96	99 31	99 635	99 47	100.22	99 84
Coarse gravel > 2 mm	.71	65	68	33	37	.35
Fine earth	99 29	99 35	99 32	99 67	99 63	99.65

TABLE XII—Results of CHEMICAL ANALYSES of soil and subsoil of 8 unfertilized plots of Ohio State University Farm, Columbus, O. Wheat Section. (*Falkenbach.*)

Plot No	1	4	7	10	13	16	19	22	Av.
SOIL									
Insoluble matter / Soluble silica	83 49	82 78	83 34	83.10	83.47	82 78	83 60	84.93	83.44
Potash (K_2O)	0.64	0.53	.62	.55	.59	.53	.62	.43	.56
Soda (Na_2O)	0.69	0.69	.77	83	93	.68	73	.56	.74
Lime (CaO)	0.64	0.60	.59	.46	.45	.63	.68	.45	.56
Magnesia (MgO)	0.76	0.52	.71	.64	.61	.58	.62	.49	.62
Ferric oxid (Fe_2O_3)	3.18	3.11	4.21	3.85	3 43	2.99	3.28	3.20	3.41
Alumina (Al_2O_3)	4.71	5.11	4 99	4 93	4 82	5.05	4.66	4.52	4.85
Phosphorus pentoxid (P_2O_5)	0.12	0.20	.17	.17	.15	.10	.11	.12	.14
Sulfur trioxid (SO_3)	0.09	0.09	.04	.09	.12	.08	.08	.10	.09
Water and organic matter	5.63	6.53	5.02	5.70	5.88	6.52	5.70	5.90	5.86
Total	99 95	100.19	100.46	100 32	100 45	99.94	100.08	100.70	100.27
Total nitrogen	0.24	0.28	.21	.35	.18	.39	.17	.17	.25
Carbon									1.853
SUBSOIL									
Insoluble matter / Soluble silica	84.09	82.24	84.24	83.52	84 11	83.89	84.18	84.69	83.87
Potash (K_2O)	.40	.71	.71	.64	.45	.69	.40	.47	.56
Soda (Na_2O)	.69	.72	.76	.74	.92	1.09	.79	.54	.78
Lime (CaO)	.47	1.00	.56	.58	.36	1.10	.67	.77	.69
Magnesia (MgO)	.61	.62	.67	.73	.60	.60	.60	.56	.62
Ferric oxid (Fe_2O_3)	3.46	3.78	4 20	4.14	3.16	3 57	3.57	3.14	3.63
Alumina (Al_2O_3)	4.26	4.73	4.00	4.11	3.93	4.18	4.52	4.35	4.26
Phosphorus pentoxid (P_2O_5)	.17	.16	.17	.15	.13	.14	.15	.11	.15
Sulfur trioxid (SO_3)	.13	.11	.05	.06	.09	.13	.12	.10	.10
Water and organic matter	5.61	5.72	5.11	5.88	7.03	4.56	5.56	5.71	5.65
Total	99.89	99.79	100.47	100.55	100.78	100.29	100 22	100.44	100 30
Total nitrogen	.10	.21	.10	.21	.14	.14	.11	.07	135
Carbon									1.75

TABLE XIV.—Results of MECHANICAL ANALYSES of 6 unfertilized plots of the Northeastern Test Farm, Strongsville: Blake Tract, East and West, Sections A, B and C.

TRACT, SECTION AND PLOT	EAST TRACT				WEST TRACT			
	SEC. A.	SEC. B	SEC. C.		SEC. A	SEC. B.	SEC. C	
	PLOT 13	PLOT 31	PLOT 13		PLOT 4	PLOT 17	PLOT 17	
SOIL								
Sample No	[illegible]	[illegible]	1863	Av'age	1874	1880	1884	Av'age
Very coarse sand	1.27	2.11	3.05	2.14	2.85	1.61	2.06	2 17
Coarse sand (1-.5 mm)	2.86	2.23	2.92	2 67	2 32	1 36	2 25	1 97
Medium sand (.5-.25 mm)	2.75	1.71	1.83	2.10	1.41	1 81	2 80	2 01
Fine sand (.25-.1 mm)	6.81	4 60	3.71	5 05	4.40	3 32	4 35	4.02
Very fine sand (.1-.05 mm)	14 48	12 76	10.89	12 71	12 41	8.22	11 64	10 75
Total sand	**28.17**	**23.41**	**22.43**	**24.67**	**23.39**	**16.32**	**23.10**	**20.93**
Silt (.05-.01)	30 04	30.86	30.12	30 34	30 69	32 10	24.63	29 14
Fine silt (.01-.005 mm)	28.30	30 93	32.28	30 50	32 92	33.72	34 49	33.71
Total silt	**58.34**	**61.79**	**62.40**	**60.84**	**63.61**	**65.82**	**59.12**	**62.85**
Clay (.005-.0001 mm)	5.16	8.71	7 51	7 13	6.92	10.11	10 95	9 32
Total mineral matter	**91.67**	**93.91**	**92.31**	**92.64**	**93.92**	**92.25**	**93.17**	**93.10**
Moisture, loss at 100° C	1 43	1.74	1 72	1 63	1.40	2.51	1.42	1 78
Loss on ignition	6 26	4 72	4 71	5 24	4.96	5.49	4.84	5 10
Total	99.36	100 77	93.80	99.51	100 28	100 25	99.43	99 08
Coarse gravel > 2 mm	5 03	2 77	4 70	4 17	2 58	3.84	4 78	3 73
Fine earth	94 97	97 23	95 20	95 83	97.42	96.16	95.22	96 27
SUBSOIL								
Sample No	[illegible]	[illegible]	1869	Av'age	1875	1881	1885	Av'age
Very coarse sand	1.02	.58	.69	.76	.86	.45	1.36	.89
Coarse sand (1 .5 mm)	2.18	.42	.66	1 09	1 24	.92	1.96	1 37
Medium sand (.5-.25 mm)	2 27	.86	.62	1.25	1 59	1 40	2 55	1.85
Fine sand (-25-.1 mm)	6 45	2 21	1.52	3.39	3 88	3 35	6.22	4 48
Very fine sand (.1-.05 mm)	11 22	5.96	3.48	6 89	10 33	4 89	12 59	9 24
Total sand	**23.14**	**10.03**	**6.97**	**13.33**	**17.90**	**11.01**	**24.59**	**17.83**
Silt (.05-.01 mm)	35 20	35 59	30 04	33 61	27 56	27 16	23 06	25 93
Fine silt (.01-.005 mm)	26 60	32 21	35 24	31 35	30 63	34.33	29 35	31 43
Total silt	**61.80**	**67.80**	**65.28**	**64.96**	**53.19**	**61.49**	**52.41**	**57.40**
Clay (.005-.0001 mm)	11.55	16 62	21.81	16 66	17 01	21 68	17 08	18 59
Total mineral matter	**96.49**	**94.45**	**94.63**	**95.01**	**93.10**	**94.18**	**94.08**	**93.78**
Moisture, loss at 100° C	1.92	2 01	2 26	2.06	2.92	1.98	2 13	2 34
Loss on ignition	2 52	3 80	4.36	3 56	4 18	4 11	3 93	4 07
Total	100.93	100 26	100 68	100 63	100 20	100 27	100 14	100 19
Coarse gravel > 2 mm	2.41	1 95	1 18	1.85	.89	5 88	1 03	2 60
Fine earth	97 59	98 05	98.82	98 15	99 11	94.12	98 97	97.40

TABLE XV.—Results of CHEMICAL ANALYSES of 6 unfertilized plots of the Northeastern Test Farm, Strongsville: Blake Tract, East and West, Sections A, B and C.

PLOT AND SECTION NO.	EAST				WEST			
	SEC. A	SEC. B	SEC. C		SEC. A	SEC. B	SEC. C	
	PLOT 13	PLOT 31	PLOT 13		PLOT 4	PLOT 17	PLOT 17	
	SOIL				SOIL			
Sample No	1852	1864	1868	Av.	1874	1880	1884	Average
Insoluble matter / Soluble silica	84.71	87.09	84.22	85.34	88.37	84.77	85.96	86.37
Potash (K_2O)	.18	.25	.22	.22	.21	.20	.25	.22
Soda (Na_2O)	.22	.22	.22	.22	.16	.26	.15	.19
Lime (CaO)	.20	.16	.10	.15	.19	.23	.28	.23
Magnesia (MgO)	.44	.31	.54	.43	.34	.40	.40	.38
Ferric oxid (Fe_2O_3)	3 19	2.43	3.34	2.99	2.58	3.27	2.81	2.89
Alumina (Al_2O_3)	2.93	2 67	3.96	3.19	.96	3 01	4.15	2.71
Phosphorus pentoxid (P_2O_5)	.097	.064	.121	.094	.099	.08	.12	. 9
Sulfur trioxid (SO_3)	.03	.01	.04	.03	.04	.04	.06	.05
Water and organic matter	7 82	6.19	7.03	7.01	6 36	7 30	6 26	6.64
Total	99 81	99.39	99.79	99.67	99.30	99.56	100 44	99.77
Total nitrogen	.185	.14	......	.162	.144	......	121	.132

	EAST				WEST			
	SUBSOIL				SUBSOIL			
Sample No	1853	1865	1869	Av.	1875	1881	1885	Average
Insoluble matter / Soluble silica	87.03	84.35	82.32	84 57	80.98	83.37	80.82	81.72
Potash (K_2O)	.21	.25	.21	.22	.25	.12	.25	21
Soda (Na_2O)	.15	.20	.40	.25	.29	.27	.27	.28
Lime (CaO)	.12	.15	.25	.18	.27	.20	.16	.21
Magnesia (MgO)	.48	.47	.38	.44	.58	.46	.57	.54
Ferric oxid (Fe_2O_3)	3.80	4.86	5.92	4.86	4.78	6.76	4.78	5 44
Alumina (Al_2O_3)	3 76	3.93	4.62	4.10	5.10	2.44	5.59	4.38
Phosphorus pentoxid (P_2O_5)	.062	.059	.11	.077	.117	.071	.179	.122
Sulfur trioxid (SO_3)	.02	.03	.021	.024	.07	.03	.06	.05
Water and organic matter	4.20	5 53	5.57	5.10	7.33	6.46	7 15	6.98
Total	99.83	99.82	99.80	99.81	99.76	100.18	99 82	99.87
Total nitrogen	.061	.072		.066	.075		.075	075

TABLE XVI. Results of MECHANICAL ANALYSES of 12 unfertilized plots of the Northeastern Test Farm, Strongsville; Pomeroy Tract, Sections A, B, C, D and E.

SECTION AND PLOT	SEC. A		SEC. B		SEC. C			SEC. D			SEC. E		
	PL 4	PL 2	PL 1	PL 4	PL 4	PL 16	PL 40	PL 4	PL 16	PL 28	PL 16	PL 28	
SOIL													
Sample No	1810	1814	1820	1824	1826	1828	1832	1834	1836	1838	1844	1846	Av.
Very coarse sand	2.57	1.22	2.29	.29	1.00	.90	1.48	1.33	2.45	1.99	1.29	1.60	1.53
Coarse sand (1-.5 mm)	2.32	2.15	2.51	1.71	2.40	2.79	2.39	1.36	3.05	2.94	2.92	2.56	2.42
Medium sand (.5-.25 mm)	1.76	2.24	2.12	2.47	2.80	2.47	2.63	1.15	3.00	3.14	3.47	2.25	2.46
Fine sand (.25-.1 mm)	3.55	3.37	4.67	4.75	6.69	5.91	5.33	6.03	6.96	7.46	5.95	5.14	5.44
Very fine sand (.1-.05 mm)	10.11	8.33	6.71	9.63	12.48	8.95	9.39	15.70	11.90	10.61	7.65	9.59	10.09
Total sand	**20.31**	**17.31**	**17.7[illegible]**	**18.85**	**25.37**	**21.05**	**21.22**	**25.57**	**27.26**	**26.14**	**21.28**	**21.14**	**21.94**
Silt (.05-.01 mm)	19.11	32.13	27.12	22.45	24.68	24.19	13.20	25.67	32.02	31.42	28.55	27.46	25.66
Fine silt (.01-.005 mm)	44.30	37.37	39.1[illegible]	40.95	[illegible]7.46	37.42	45.20	34.18	27.87	28.68	33.3[illegible]	35.28	36.76
Total silt	**63.41**	**69.50**	**66.2[illegible]**	**63.43**	**62.14**	**61.61**	**58.40**	**59.73**	**59.89**	**60.10**	**61.[illegible]**	**62.74**	**62.42**
Clay (.005-.0001 mm)	6.90	6.31	7.61	10.22	5.78	8.03	9.45	4.66	3.18	3.61	7.15	7.06	6.66
Total mineral matter	**90.62**	**93.12**	**91.58**	**92.47**	**93.29**	**90.69**	**89.07**	**90.06**	**90.43**	**89.85**	**90.29**	**90.94**	**91.03**
Moisture, loss at 100° C	1.90	1.02	1.15	1.63	.98	2.70	3.06	1.60	1.93	2.03	2.20	1.65	1.82
Loss on ignition	6.44	6.24	7.69	6.21	5.79	7.31	7.65	8.51	6.87	8.18	7.73	7.55	7.18
Total	98.96	100.38	100.42	100.31	100.06	100.70	99.78	100.20	99.23	100.06	100.22	100.14	100.03
Coarse gravel > 2 mm	2.36	2.06	5.67	6.04	5.04	2.25	2.12	3.70	2.33	5.01	3.58	2.34	3.54
Fine earth	97.64	97.94	94.33	93.96	94.96	97.75	97.88	96.30	97.67	94.99	96.42	97.66	96.46
SUBSOIL													
Sample No	1811	1815	1821	1825	1827	1829	1833	1835	1837	1839	1845	1847	Av.
Very coarse sand	1.59	.36	.77	.60	1.16	1.17	1.44	1.38	.86	1.47	.97	.46	1.02
Coarse sand (1-.5 mm)	1.49	.73	.87	.79	.200	1.75	2.03	1.12	1.82	2.22	1.93	1.19	1.49
Medium sand (.5-.25 mm)	1.40	.77	.85	1.41	2.58	2.25	1.61	2.52	3.51	2.92	2.24	1.46	1.96
Fine sand (.25-.1 mm)	2.95	1.73	5.04	4.05	5.16	5.02	3.57	4.52	7.65	6.95	4.56	3.65	4.65
Very fine sand (.1-.05 mm)	7.06	3.27	9.99	5.17	8.93	7.98	6.06	10.68	13.70	13.00	8.73	6.00	8.39
Total sand	**14.49**	**6.86**	**17.52**	**12.02**	**19.83**	**18.17**	**14.71**	**20.22**	**27.54**	**26.56**	**18.43**	**12.76**	**17.50**
Silt (.05-.01 mm)	29.20	27.05	29.32	21.39	30.14	29.05	25.62	29.72	25.00	27.80	26.40	23.09	26.98
Fine silt (.01-.005 mm)	35.62	43.69	35.66	40.69	34.53	32.00	38.47	33.58	28.82	26.95	34.13	37.20	35.11
Total silt	**64.82**	**70.74**	**64.98**	**62.08**	**64.67**	**61.05**	**64.09**	**63.20**	**53.82**	**54.75**	**60.53**	**60.29**	**62.08**
Clay (.005-.0001 mm)	14.21	17.93	14.07	17.98	10.93	15.43	14.61	11.51	13.55	14.17	15.51	20.29	15.01
Total mineral matter	**93.52**	**95.53**	**96.57**	**92.08**	**95.43**	**94.65**	**93.41**	**95.03**	**94.91**	**95.48**	**94.47**	**93.34**	**94.54**
Moisture, loss at 100° C	2.71	1.00	.99	2.80	.90	2.01	1.88	1.20	1.40	1.21	2.53	2.31	1.75
Loss on ignition	3.95	4.01	3.20	5.15	4.03	3.96	4.65	4.28	3.52	4.26	3.18	4.51	4.05
Total	100.21	100.54	100.76	100.03	100.36	100.62	99.91	100.51	99.83	100.95	100.18	100.16	100.34
Coarse gravel > 2 mm	1.01	.94	7.04	3.96	2.38	2.36	2.52	.90	2.67	6.20	5.01	5.31	3.34
Fine earth	98.99	99.06	92.96	96.04	97.62	97.64	97.48	99.10	97.33	93.80	94.99	94.69	96.66

TABLE XVII.—Results of CHEMICAL ANALYSES of 7 unfertilized plots of the Northeastern Test Farm, Strongsville: Pomeroy Tract, Sections A, B, C, D and E.

SECTION AND PLOT NO.	SECTION A	SECTION B	SECTION C		SECTION D	SECTION E		
	PLOT 4	PLOT 16	PLOT 4	PLOT 40	PLOT 28	PLOT 16	PLOT 28	
SOIL								
Sample No	1810	1820	1826	1832	1838	1844	1846	Av
Insoluble matter / Soluble silica	85 57	78 24	82 86	80 28	80 27	81.96	82 25	81 63
Potash (K_2O)	.23	.19	19	28	20	.11	15	.19
Soda (Na_2O)	.10	.50	.58	17	52	.29	.33	.34
Lime (CaO)	.19	.180	.27	.30	.354	.23	.22	.25
Magnesia (MgO)	.42	.56	.461	.57	44	.54	.50	.50
Ferric oxid (Fe_2O_3)	2 73	4 48	3 04	3.72	3 19	3 42	3.87	3 49
Alumina (Al_2O_3)	1 87	4 53	3 86	3 21	4 69	3 60	3 04	3 54
Phosphorus pentoxid (P_2O_5)	.197	.161	113	.227	.126	.126	.121	.153
Sulfur trioxid (SO_3)	.05	.055	.057	07	.059	05	.05	.06
Water and organic matter	8.34	10.88	8 93	10 79	9 92	9 37	8.91	9 60
Total	99 69	99 78	100.36	99 61	99 77	99 69	99 44	99 76
Total nitrogen	.204	.256	.195		.244	.198		.219
SUBSOIL								
Sample No	1811	1821	1827	1833	1839	1845	1847	Av.
Insoluble matter / Soluble silica	84.07	84.14	84.27	85 62	85.71	84 44	82 33	84.37
Potash (K_2O)	.32	.20	.19	.22	.20	.16	.21	.21
Soda (Na_2O)	.18	44	.45	.16	.50	.27	.28	.32
Lime (CaO)	18	.103	.146	.15	.236	.15	.16	.17
Magnesia (MgO)	.51	.539	54	.41	.489	.22	.24	.42
Ferric oxid (Fe_2O_3)	4 18	4 40	3.72	3 99	4.10	4 71	5.32	4.35
Alumina (Al_2O_3)	3.72	4 41	4.81	2 61	3.82	4 19	4 43	3.99
Phosphorus pentoxid (P_2O_5)	.096	.06	.062	.124	.04	.07	.131	.08
Sulfur trioxid (SO_3)	05	.014	.019	.04	.021	.02	.02	.03
Water and organic matter	6.69	5.17	5 55	6.53	4.72	5 81	6 28	5 82
Total	.9.99	99 47	99 76	99.85	99.83	100 04	99.40	9.) 76
Total nitrogen	.079	.065	.090		.077	.076		08

TABLE XVIII.—MECHANICAL ANALYSES of 3 samples of yellow sand from unfertilized plots of the former Northwestern Test Farm, Neapolis, O.

PLOT NO.	PLOT 4	PLOT 22	Un-plotted		PLOT 4	PLOT 22	Un-plotted	
	SOIL				SUBSOIL			
Sample No	1786	1792	1804*	Ave.	1787	1793	1805*	Ave.
Very coarse sand	......	34	05	13	....	48	.45	.31
Coarse sand (1-.5 mm)	.26	1 68	1 14	1 03	34	1 85	1 82	1.34
Medium sand (.5-.25 mm)	1.60	4 66	3 85	3 37	1 06	4 08	3.88	3.00
Fine sand (.25-.1 mm)	31 47	39 40	41 77	37 54	31 11	35 95	31.28	32.78
Very fine sand (.1-.05 mm)	53 28	42 64	42 96	46 29	58 09	47 65	50.60	52.11
Total sand	**86 61**	**88 72**	**89 77**	**88.36**	**90 60**	**90.01**	**88.03**	**89.54**
Silt (.05-.01 mm)	2.50	2 87	2 35	2 57	82	2 57	3.82	2.40
Fine silt (.01-.005 mm)	3 72	3 42	3.06	3 40	3 05	2 77	2.47	2.76
Total silt	**6 22**	**6.29**	**5.41**	**5 97**	**3.87**	**5 34**	**6.29**	**5.16**
Clay (.005-.0001 mm)	1 62	2.80	2 97	2.47	1.96	2.70	2.52	2.40
Total mineral matter	**94 45**	**97 81**	**98.15**	**96.80**	**96 43**	**98.05**	**96.84**	**97.11**
Moisture, loss at 100° C	.99	1.02	.90	.97	.81	.95	1.33	1.03
Loss on ignition	4 14	1.90	1.26	2 43	1.90	.65	1.00	1.18
Total	99 58	100.73	100 31	100.20	99.14	99.65	99.17	99 32
Coarse gravel > 2 mm	.....	......	......	......	......	......	......	......
Fine earth	100 00	100 00	100 00	100.00	100.00	100.00	100.00	100.00

* Chemical analyses not made of Nos. 1804 and 1805.

TABLE XIX.—CHEMICAL ANALYSES of 2 samples of yellow sand from unfertilized plots of the former Northwestern Test Farm, Neapolis, O.

PLOT NO.	PLOT 4	PLOT 22		PLOT 4	PLOT 22	
	SOIL			SUBSOIL		
Section No	1786	1792	Average.	1787	1793	Average.
Insoluble matter / Soluble silica	92.09	94.33	93.21	93.98	94.64	94.31
Potash (K_2O)	**.046**	**.06**	**.053**	**.04**	**.09**	**.06**
Soda (Na_2O)	.06	.06	.06	.08	.06	.07
Lime (CaO)	**.07**	**.31**	**.19**	**.07**	**.22**	**.14**
Magnesia (MgO)	.10	.14	.12	.11	.15	.13
Ferric oxid (Fe_2O_3)	1.00	.99	.995	1.00	.65	.82
Alumina (Al_2O_3)	1.10	.88	.99	2.15	1.80	1.97
Phosphorus pentoxid (P_2O_5)	**.120**	**.13**	**.125**	**11**	**.12**	**.12**
Sulfur trioxid (SO_3)	.03	.032	.031	.02	.021	.020
Water and organic matter	5.13	2 78	3.95	2.75	1.83	2.29
Total	99.74	99.71	99.73	100.31	99.58	99.94
Total nitrogen	.091	.....	.091	.037	......	.037

TABLE XX.—Results of MECHANICAL ANALYSES of 2 samples of black sand from unfertilized plots from the former Northwestern Test Farm, Neapolis, Ohio.

	SOIL			SUBSOIL		
	Un-plotted	Un-plotted		Un-plotted	Un-plotted	
Sample No	1802	1806	Average.	1803	1807	Average.
Very coarse sand	......	.05	03	......	.09	.04
Coarse sand (1-.5 mm)	1.05	.57	.81	.94	.59	.77
Medium sand (.5.25 mm)	2.74	2.88	2.81	2.64	2.44	2.54
Fine sand (.25-.1 mm)	33.71	29.30	31.52	30.70	33.70	32.20
Very fine sand (.1-.05 mm)	49.91	53.28	51.59	54.03	49.16	51.59
Total sand	87.44	86.08	86.76	88.31	85.98	87.14
Silt (.05.01)	1.35	3 06	2.21	2.22	4 69	3.46
Fine silt (.01-.005 mm)	2.99	2 61	2 80	2.85	2 65	2.75
Total silt	4.34	5.67	5 01	5 07	7.34	6.21
Clay (.005-.0001 mm)	.90	1 55	1.22	1 40	2.74	2.07
Total mineral matter	92.68	93.30	92 99	94.78	96.06	95.42
Moisture, loss at 100° C	1 23	1.20	1.21	1.40	1.29	1.34
Loss on ignition	4.74	6.29	5.52	4 32	2.00	3.16
Total	98.65	100.79	99.72	100.50	99.35	99.92
Coarse gravel > 2 mm	...	.	......	......	. .	......
Fine earth	100.00	100 00	100.00	100.00	100 00	100.00

TABLE XXI.—Results of CHEMICAL ANALYSES of 2 samples of black sand from unfertilized plots of the former Northwestern Test Farm, Neapolis, O.

	SOIL			SUBSOIL		
	Un-plotted	Un-plotted		Un-plotted	Un-plotted	
Sample No	1802	1806	Average.	1803	1807	Average.
Insoluble matter / Soluble silica	91.61	89.14	90.37	93.15	93.22	93.18
Potash (K_2O)	.05	.05	.05	.06	.06	.06
Soda (Na_2O)	.07	.10	.09	.06	.12	.09
Lime (CaO)	.11	.49	.30	.08	.41	.24
Magnesia (MgO)	.09	.18	.13	.14	15	.14
Ferric oxid (Fe_2O_3)	.54	.80	.67	1.15	1.10	1.12
Alumina (Al_2O_3)	.66	.93	.80	1.43	1 26	1.34
Phosphorus pentoxid (P_2O_5)	.11	.16	.14	.10	.12	.11
Sulfur trioxid (SO_3)	.03	.034	03	.01	.018	.014
Water and organic matter	6.07	8.27	7 17	4.32	3.24	3.78
Total	99.34	100.15	99.74	100.50	99.698	100.099
otal nitrogen	.120	......	.120	.113	....	.113

TABLE XXII.—Results of MECHANICAL ANALYSES of 1 sample of soil and subsoil of Germantown Test Farm and 2 samples of same of Carpenter Test Farm.

	GER-MAN-TOWN	CARPENTER			GER-MAN-TOWN	CARPENTER		
		Corn Field	Wheat Field			Corn Field	Wheat Field	
	SOIL				SUBSOIL			
Sample No	**4253**	**4255**	**4257**	Av.	**4254**	**4256**	**4258**	Av.
Very coarse sand (2-1 mm)	1 04	44	59	.515	1 19	.21	.49	.35
Coarse sand (1-.5 mm)	1 93	1 38	2 21	1 795	1 79	74	1.80	1.27
Medium sand (.5-.25 mm)	1 96	1 01	2 09	1 55	1 86	58	1.83	1 21
Fine sand (.25-.1 mm)	4 34	1 92	2 73	2.325	4.33	1.05	1 91	1.48
Very fine sand (.1-.05 mm)	9 09	4 12	5 39	4 75	12 94	4 09	2.96	3 52
Total sand	**18 36**	**8 87**	**13.01**	**10 94**	**22.11**	**6 67**	**8.99**	**7.83**
Silt (.05-01 mm)	50 21	49 43	45 40	47 415	40 96	45 89	47 11	46.50
Fine silt (.01-.005 mm)	17 72	25 86	26 16	26 01	18 43	25 43	23.81	24 62
Total silt	**67.93**	**75.29**	**71 56**	**73 42**	**59.39**	**71.32**	**70.92**	**71 12**
Clay (.005-.0001 mm)	8.89	10.00	9 12	9.71	14 58	16.91	15 11	16 01
Total mineral matter	**95 18**	**94.16**	**93 99**	**94 075**	**96 08**	**94 90**	**95.02**	**94.96**
Moisture, loss at 100° C	1 05	1 13	1.10	1.115	1.18	1 22	1.20	1.21
Loss on ignition	3 46	4 76	5 02	4 89	3.12	3 86	3.58	3.72
Total	99 69	100 05	100.11	100.08	100.38	99 98	99.80	99.89

TABLE XXIII.—Results of CHEMICAL ANALYSES of 1 sample of soil of Germantown Test Farm and 2 samples of Carpenter Test Farm.

	GER-MAN-TOWN	CARPENTER			GER-MAN-TOWN	CARPENTER		
		Corn Field	Wheat Field			Corn Field	Wheat Field	
	SOIL				SUBSOIL			
Sample No	**4253**	**4255**	**4257**	Av.	**4254**	**4256**	**4258**	Av
Insoluble matter / Soluble silica	90 55	85.31	86.14	85.73	89 20	83 55	85.95	84.75
Potash (K_2O)	**.142**	**.193**	**.181**	**.187**	**210**	**.275**	**.235**	**.265**
Soda (Na_2O)	.21	.10	.11	105	.23	.11	12	.12
Lime (CaO)	.11	18	.18	.175	.13	.19	.10	.15
Magnesia (MgO)	.31	.33	.26	.295	37	46	28	.37
Ferric oxid (Fe_2O_3)	1.68	2 81	2.65	2 73	2 26	3 82	3.12	3.47
Alumina (Al_2O_3)	3.17	3 69	4 29	3 99	3.69	5 00	4.73	4.87
Phosphorus pentoxid (P_2O_5)	**.102**	**.124**	**101**	**.112**	**.115**	**093**	**.074**	**.084**
Sulfur trioxid (SO_3)	.03	.03	03	.03	.03	.02	03	.03
Water and organic matter	3.70	7 65	6 12	6.885	3 86	6 18	4 98	5 58
Total	100.015	100 42	100.06	100 235	100 09	99 70	99.62	99.66
Total nitrogen	.090	.133	.144	.138	090	.069	.070	.070

DISCUSSION OF RESULTS.

The tables and diagrams herewith presented give the results of the investigations already mentioned, and the diagrams are intended to make the soil differences the more readily seen and apprehended; several features of these results seem to call for further discussion.

As already stated the requirements of plot experimentation, by the application of carriers of plant food, make the chemical analyses a first consideration in this work. In the future conduct of the work yet further analyses will be required of the soils of the same or adjoining plots.

In the present state of our knowledge concerning the soil function of certain constituents and the effects of culture upon the rate of exhaustion of yet others contained in the soil, it is not to be expected that any single series of analyses will present final results, or results admitting of final interpretation. We have presented herein a somewhat full series of soil analyses both mechanical and chemical of the soils in question and we do not find that elsewhere an equally full series of both chemical and mechanical analyses of the identical samples of a series of soils has as yet been published.

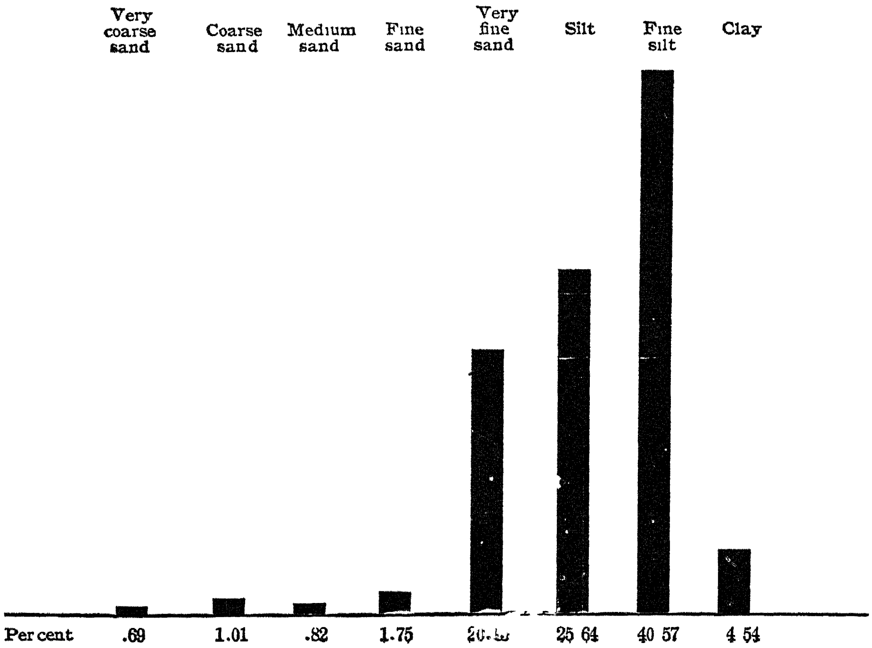
It seemed desirable and necessary, in view of the wide application already made in America of the results of mechanical sedimentation in water, as applied to soil samples, that the mechanical separations should be as complete and extended as the chemical ones. The discussion of this parallel series of analyses of the two kinds is by no means simple. Indeed to the writers it appears to offer considerable difficulties.

SIGNIFICANCE OF RESULTS OF MECHANICAL ANALYSES.

The results of the mechanical separations of the grades of sand, the silt and the clay of a soil and the statement of these amounts as percentages of the sample, convey valuable information concerning the soil character. The soils with very high percentages of total sand, like those of Neapolis, will be loose and follow the character of sand. Those with moderate percentages of total sand will be less open and loose or as described, "loamy." While those with high percentage of total silt will pack very quickly under rainfall, may harden badly and may show considerable plasticity; on the other hand the soils with much clay will be plastic, retentive of moisture with strong tendency to cloddiness in working and shrinking and cracking during drought.

TABLE XXIV.—Diagram showing the average percentages of mechanical components in the soil and subsoil of the Station Farms, Wooster.

SOIL



SUBSOIL

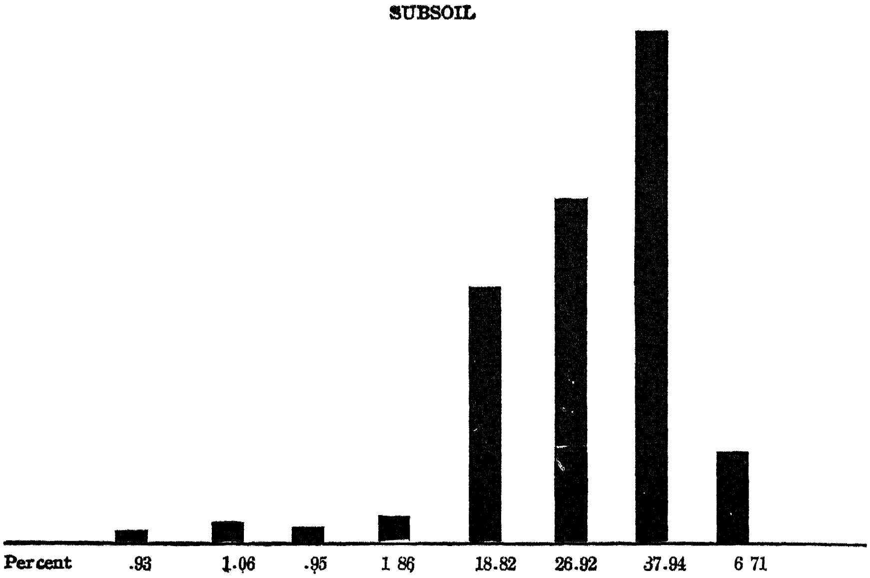
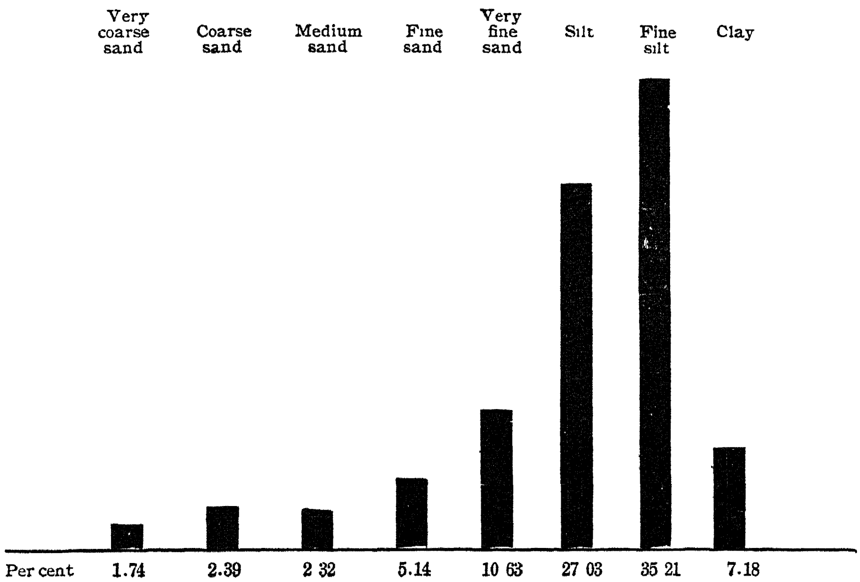


TABLE XXV.—Diagram showing the average percentages of mechanical components in the soil and subsoil of the Northeastern Test Farm, Strongsville.

SOIL



SUBSOIL

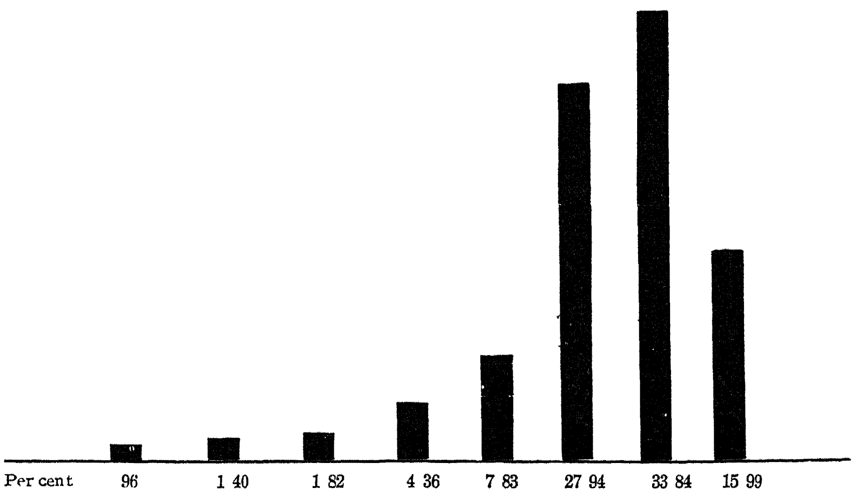
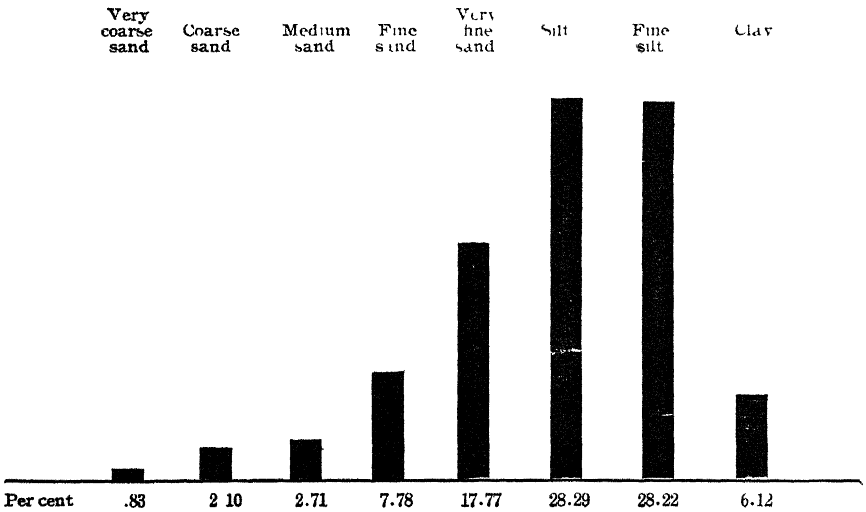


TABLE XXVI.—Diagram showing the average percentages of mechanical components in the soil and subsoil of the Ohio State University Farm, Columbus.

SOIL



SUBSOIL

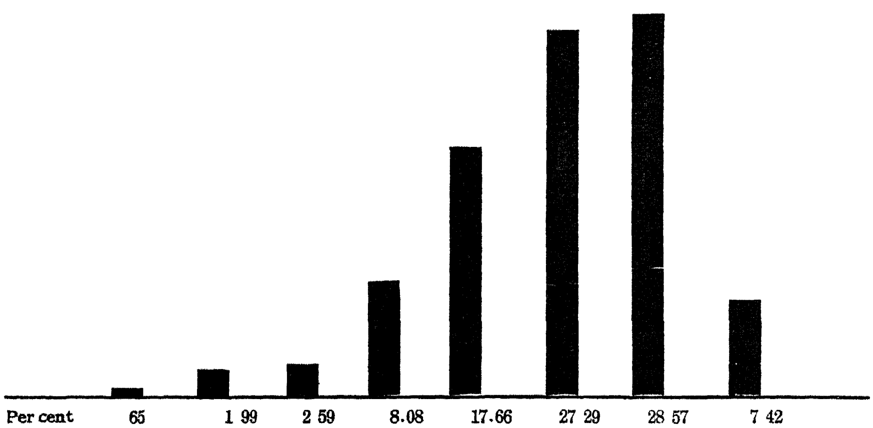


TABLE XXVII.—Diagram showing the average percentages of mechanical components in soil and subsoil of the Northwestern Test Farm, Neapolis.

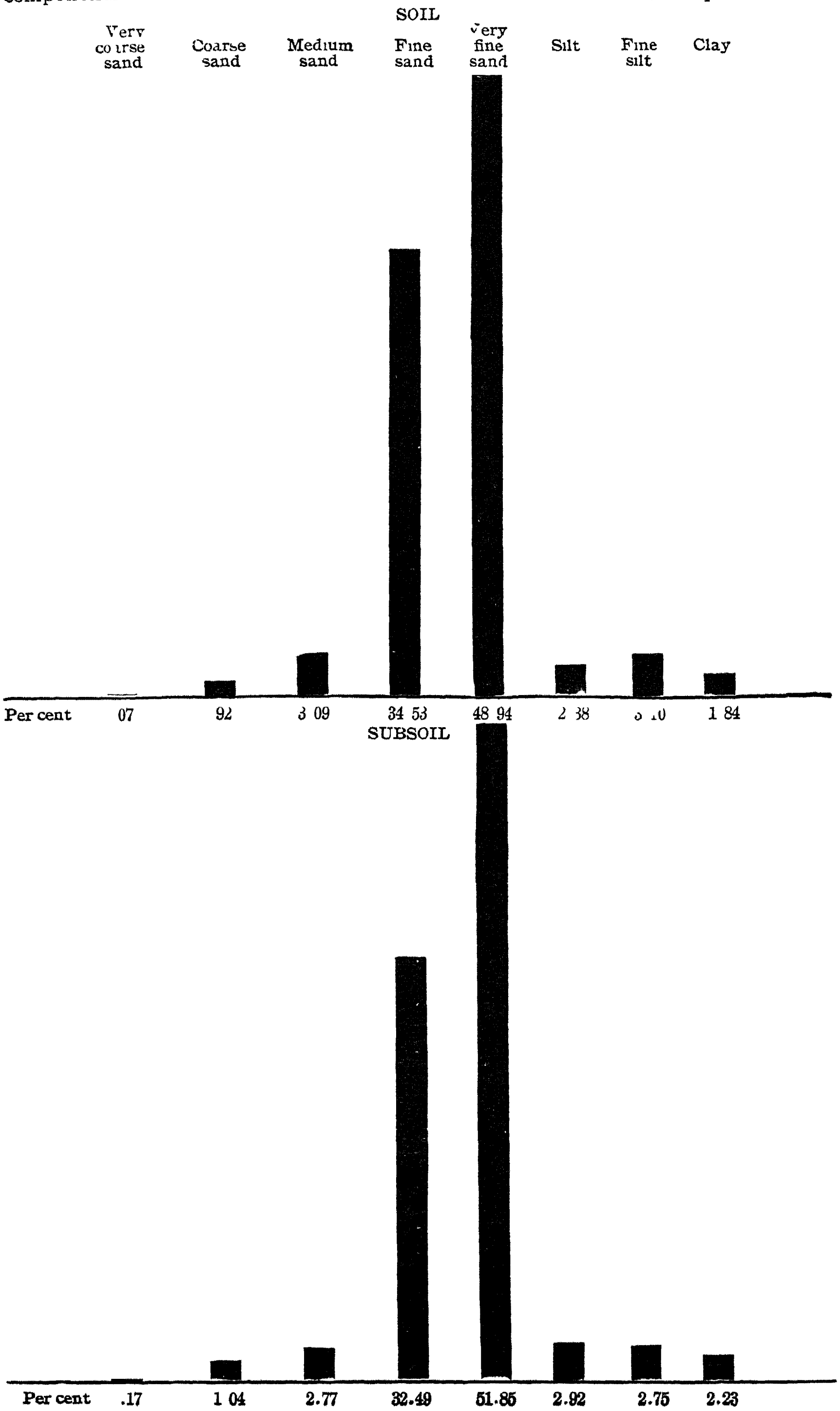
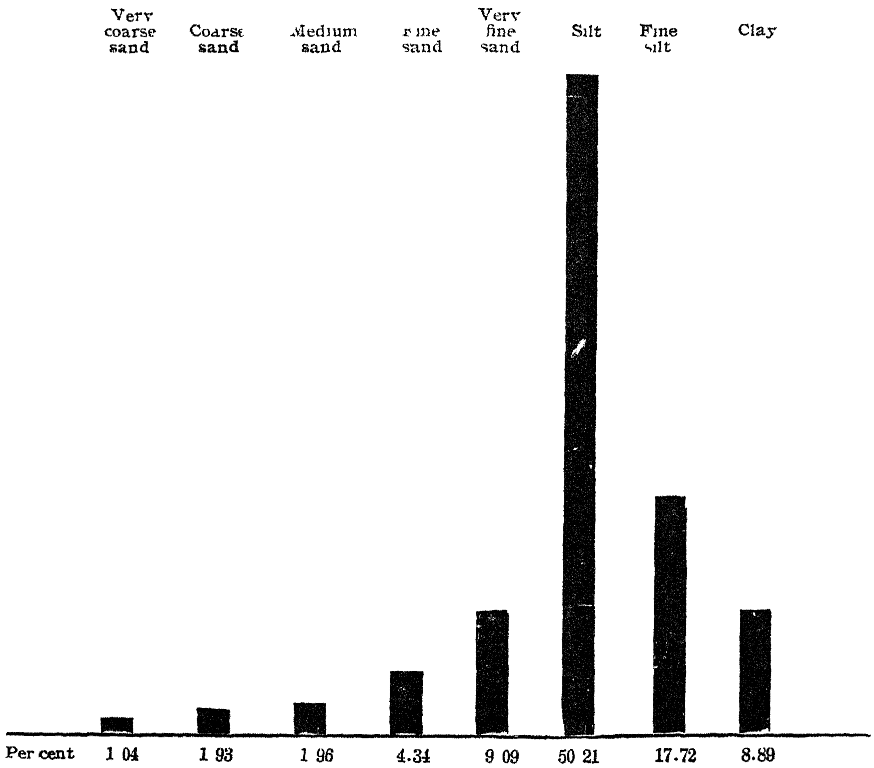


TABLE XXVIII.—Diagram showing the average percentages of mechanical components in the soil and subsoil of the Southwestern Test Farm, Germantown.

SOIL



SUBSOIL

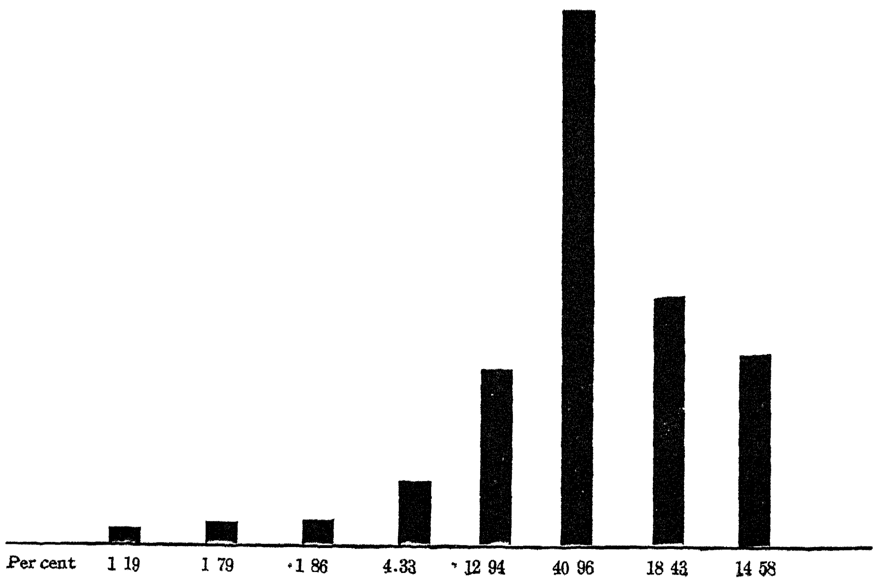


TABLE XXIX.—Diagram showing the average percentages of mechanical components in the soil and subsoil of the Southeastern Test Farm, Carpenter.

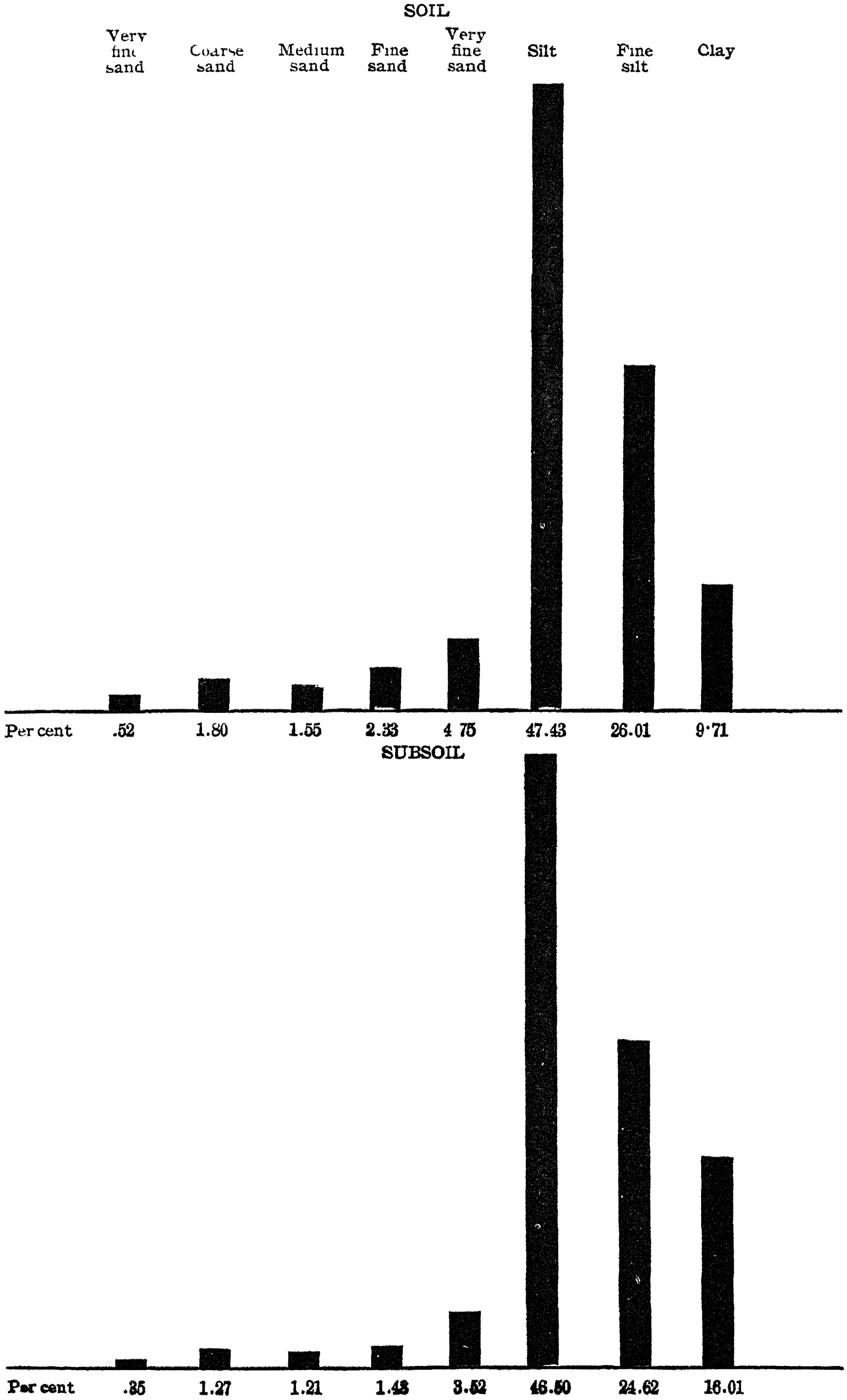
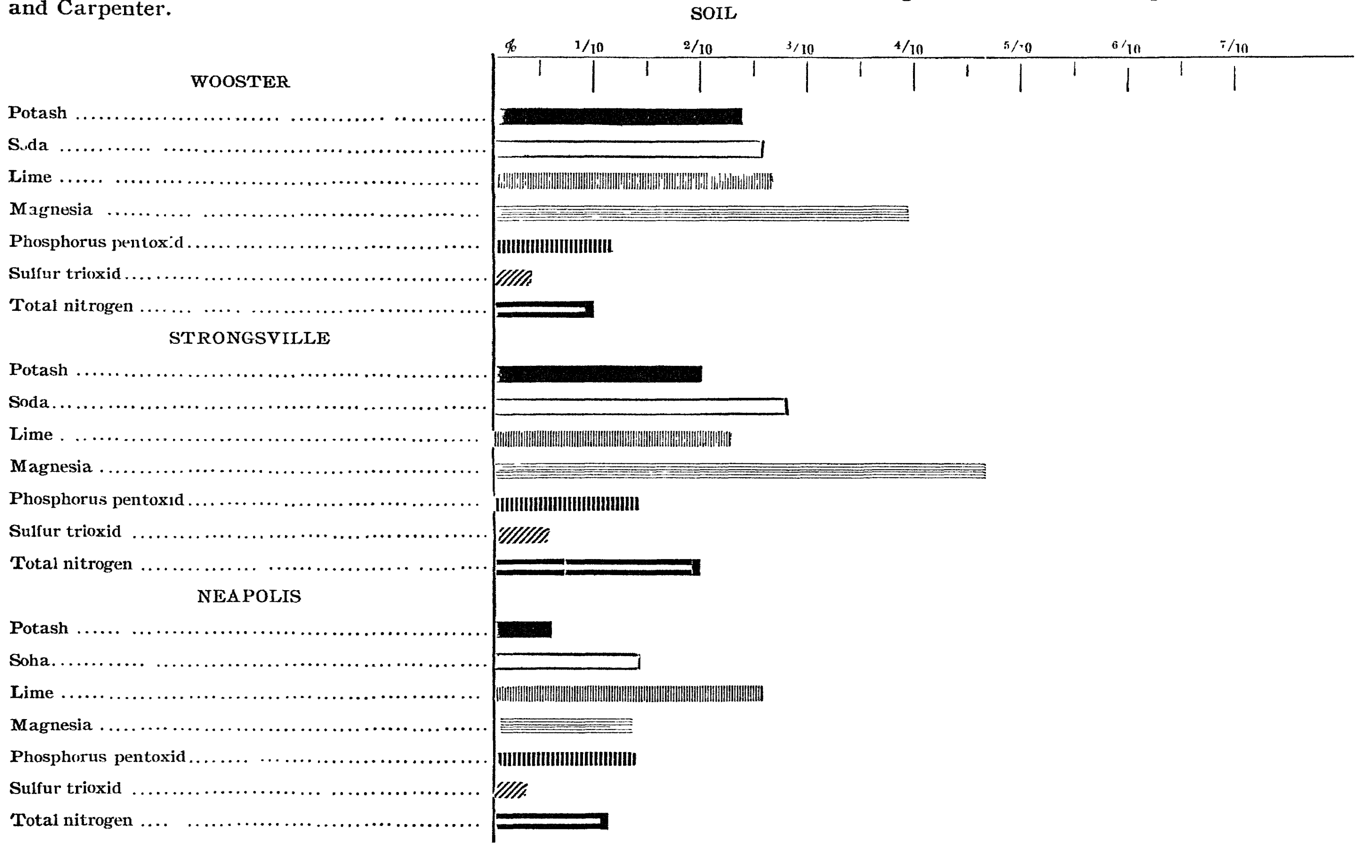


TABLE XXX.—Diagram showing the average percentages of potash, soda, lime, magnesia, phosphorus pentoxid, sulfur trioxid and total nitrogen in the SOIL, or first six inches, at Wooster, Strongsville, Columbus, Neapolis, Germantown and Carpenter.



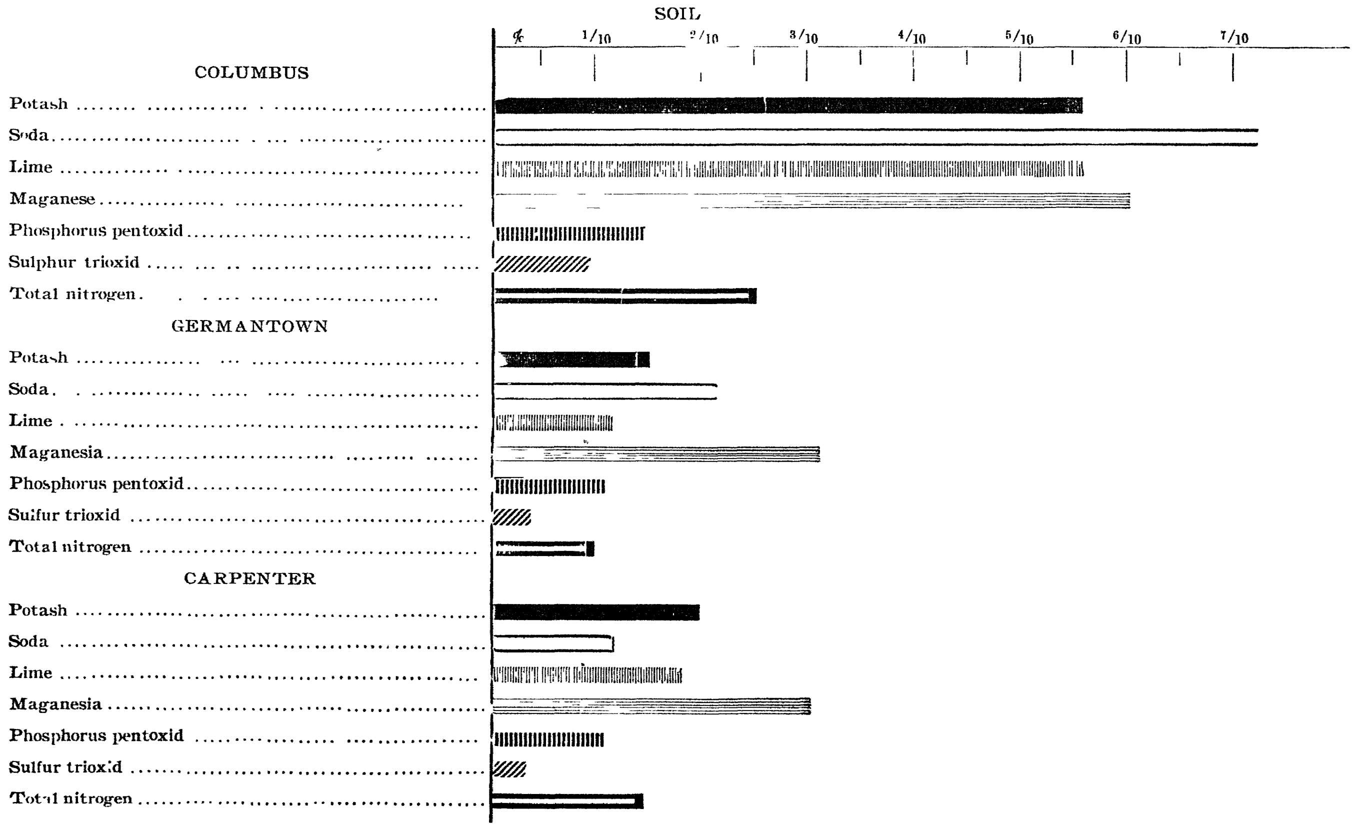
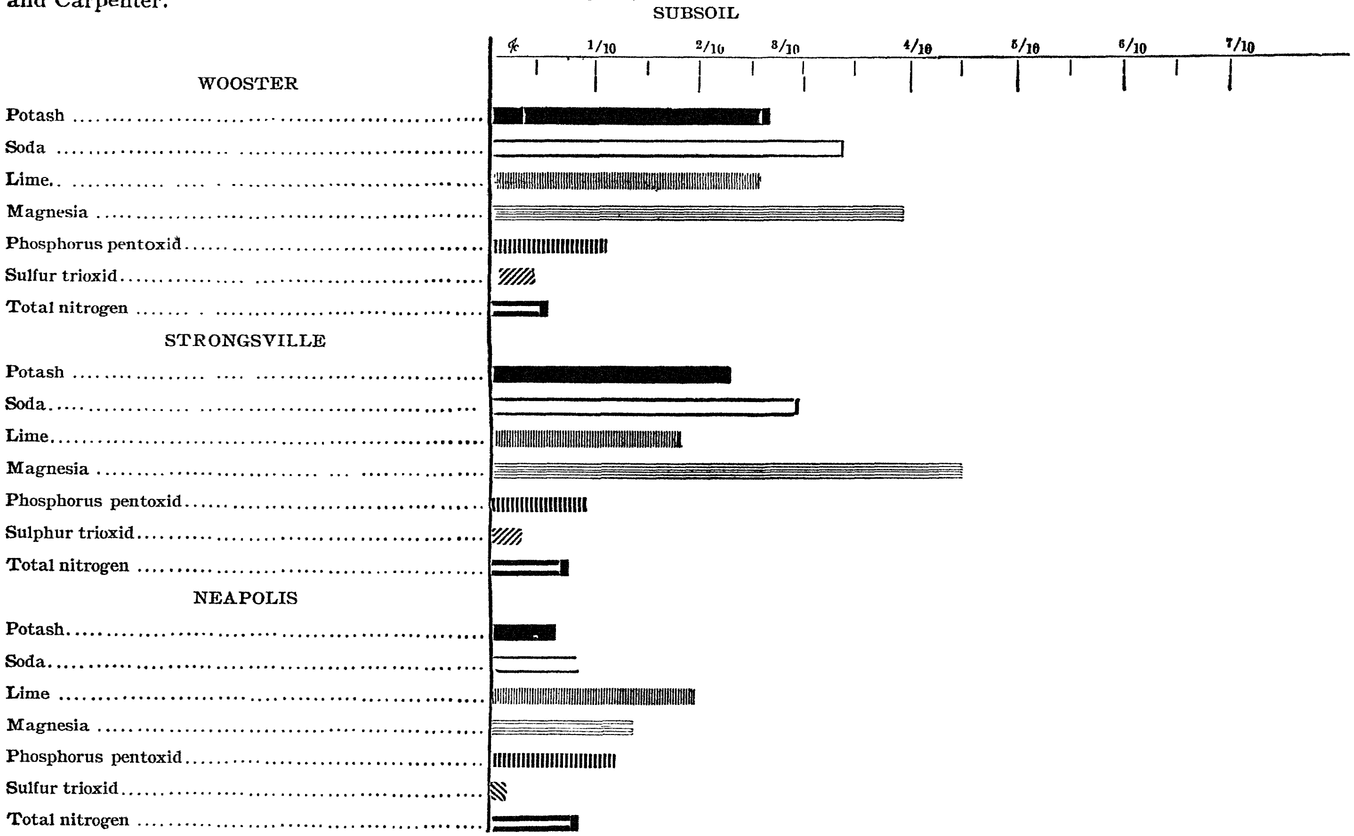
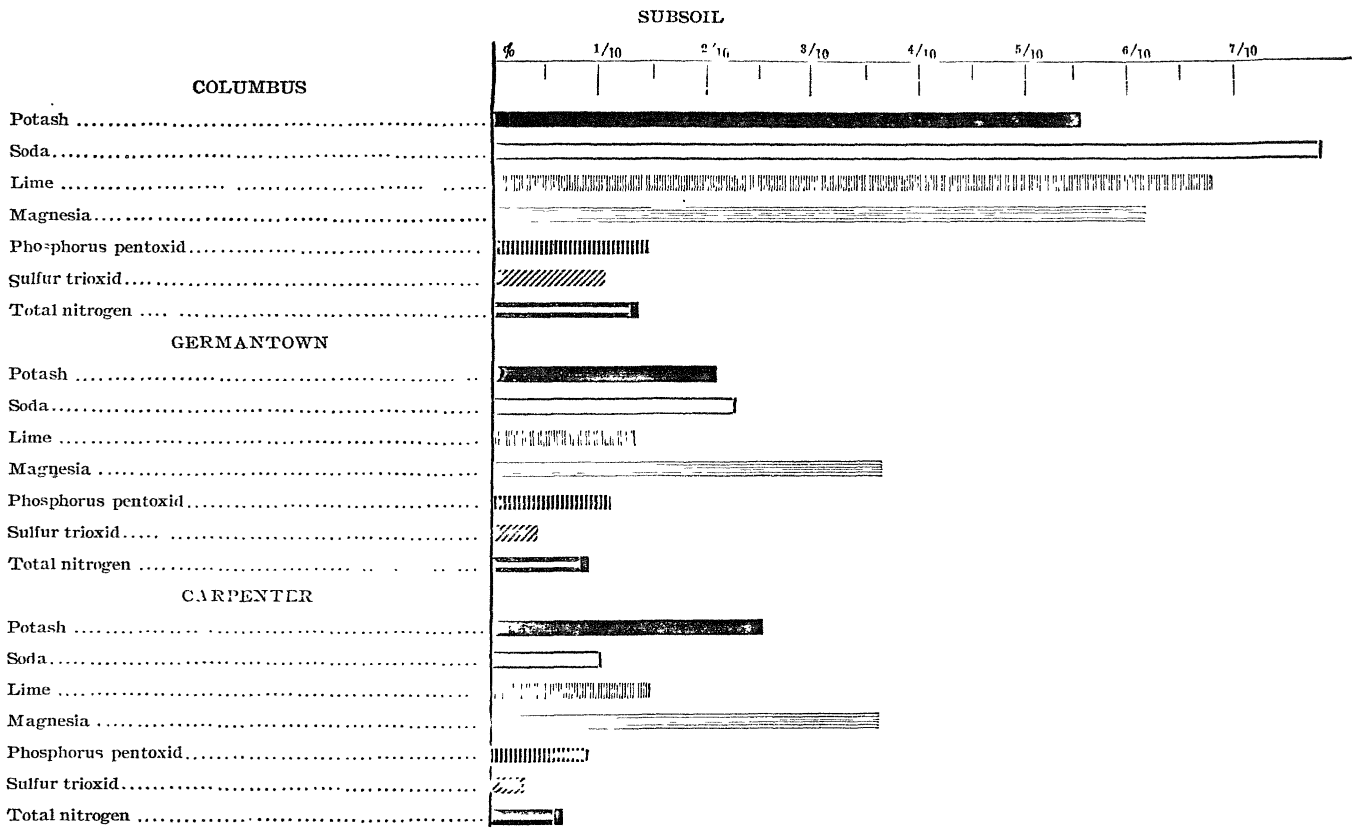

SOIL
1/10
2/10
3/10
4/10
5/10
6/10
7/10
COLUMBUS
Potash
Soda
Lime
Maganese
Phosphorus pentoxid
Sulphur trioxid
Total nitrogen
GERMANTOWN
Potash
Soda
Lime
Maganesia
Phosphorus pentoxid
Sulfur trioxid
Total nitrogen
CARPENTER
Potash
Soda
Lime
Maganesia
Phosphorus pentoxid
Sulfur trioxid
Total nitrogen

TABLE XXXI.—Diagram showing the average percentages of potash, soda, lime, magnesia, phosphorus pentoxid, sulfur trioxid and total nitrogen in the SUBSOIL, or second six inches, at Wooster, Strongsville, Columbus, Neapolis, Germantown and Carpenter.




SUBSOIL
%
1/10
2/10
3/10
4/10
5/10
6/10
7/10
COLUMBUS
Potash
Soda
Lime
Magnesia
Phosphorus pentoxid
Sulfur trioxid
Total nitrogen
GERMANTOWN
Potash
Soda
Lime
Magnesia
Phosphorus pentoxid
Sulfur trioxid
Total nitrogen
CARPENTER
Potash
Soda
Lime
Magnesia
Phosphorus pentoxid
Sulfur trioxid
Total nitrogen

When it comes to inferring the physical behavior of soils varying only in the proportions of the finer sediments, silt and clay, the difficulty increases; this difficulty may be said to prevail in the laboratory work as well as in the field culture. The possible moisture relations of soils may be inferred quite satisfactorily from mechanical analyses.

In the matter of soluble plant food, the sand will be found deficient, the silts lean and the clay richest of all; this has led to the tendency to judge the relative potential or possible productiveness of an agricultural soil by the percentage of clay contained in it. It is easy to apprehend there is here a limitation placed by the term "an agricultural soil." Outcrops of fire clay in fields are rarely productive although rich in clay. While the agricultural soil with high clay content may have a high potential productiveness, and the soil lean in clay may not be expected to possess an equal potentiality, yet at the same time it may be responsive to cultural methods, the applications of manures, and highly desirable from a cultural point of view.

We wish to present here only the broad lines of the significance of the results of mechanical analysis as applied to soils by hydraulic sedimentation. The ignition and water losses stated in the mechanical determinations are also made in the chemical analyses and will be discussed under that special heading.

METHODS AND SIGNIFICANCE OF CHEMICAL ANALYSES OF SOILS.

Chemical analyses of soils have been made for a great many years, beginning in a sense with the work of the early English, German and French agricultural chemists. Since the introduction and widespread use of phosphatic and other fertilizers some agriculturists have questioned the results of chemical analysis, because the interrelation between chemical results and soil productiveness has sometimes been clouded. In part this lack of clearness may have been due to the methods of analysis employed in earlier investigations, in part it may be due to failure to value properly the relative proportions of the various constituents, and in part it may be still due to a failure to appreciate the biological factors in the soil. The soil is indeed a biological as well as a chemical laboratory, within which biological factors interact among themselves and react upon the chemical constituents of the soil. That reactions continuously favorable to plant production may be obtained in a soil lean or poor in the elements required by the plants for their growth and maturity will scarcely be claimed by modern agronomists. But that all the differences in productiveness as between two soils of like chemical composition will be apparent from the chemical analyses will certainly be doubted by those familiar with the biological forces of crop and soil before referred to.

In the matter of methods of chemical analysis of soils, those employed have already been stated (pages 86-89) but their variation from former methods may not be apprehended.

The specified strength of hydrochloric acid and the time of digestion have been regulated so as to secure in solution the soil constituents of present agricultural value. No fusion of soil residues with alkalies to render them soluble in water or acid has been practiced except possibly in the analyses of the Columbus soils made by Mr. Falkenbach. The methods employed by him are not fully known to the writers. This digestion in a specified strength of hydrochloric acid for ten hours is the present official method of the Association of Official Agricultural Chemists of the United States and is in wide use for the reasons stated.

The results of the chemical analyses secured by this method, while not claiming to express the exact amounts of available soil plant food, etc., do express, as nearly as may be done in the present state of our knowledge, the relative amounts of elements in the soil which may be made available by culture and the proper adjustment of the plant life in and upon the soil.

The essential elements for the growth and maturity of plants including seed bearing have been determined by plant physiologists. This has been done by experiment with control of conditions. For a discussion of the details and the various bearings of the question, some work on plant physiology should be consulted. It suffices to state here that seed bearing plants require the chemical elements phosphorus, sulfur, potassium, calcium, magnesium and iron, which are commonly found in the soil in combinations of non-living or mineral nature: sodium and silicon, which also occur in like compounds, are not essential. In addition plants require nitrogen, commonly derived from living or decaying organic sources, and carbon, the latter of which is supplied in the form of a gaseous combination of carbon and oxygen called carbon dioxid, found in the atmosphere and derived from the respiration of animals and from the combustion and decay of carbonaceous bodies.

In addition and above all we may say plants require the elements hydrogen and oxygen which are, however, utilized by the plant not as hydrogen and oxygen, but as the commonest of compounds WATER, to the chemist hydrogen monoxid.

Water possesses great importance by reason of its solvent properties aside from its chemical constitution. The food of plants derived from the soil must be taken up in aqueous solutions: it needs only this statement to emphasize the primal importance of the relations of the soil to the absorption and retention of water. Yet while these ten elements of the chemist are essential and two or more others incidental in plant growth, certain of these have been found of a preponderant effect on plant growth: in this category belong potassium, phosphorus and nitrogen. Under certain unusual circumstances other elements may stand forth in importance.

What then are the elements contained in the soils analyzed and what relation do these bear to the soil productiveness? It is easier to state the results of the chemical analyses in terms of the elements found in the soil than to point out their exact relations to plant growth in every case. The content of our soils in potassium, sodium, calcium, magnesium, iron, aluminium, sulfur, carbon, nitrogen, combined oxygen, etc., are set forth in Table XXXII which is derived from Table III.

It will be observed that the percentages of these various elements, aside from carbon not previously determined, and combined oxygen, which in the earlier table was included in the oxids of all elements except nitrogen, bear a definite relation to the percentages of potash, soda, lime, magnesia, iron oxid, alumina, phosphorus pentoxid and sulfur trioxid, given in the earlier table; they have been calculated from the former percentages. To the student of chemistry these percentages are interchangeable expressions bearing certain definite mathematical relations to each other, since the chemical elements enter into combinations always in certain definite proportions by weight, which can be expressed numerically and have been so expressed for a long time in terms of atomic weights or combining proportions. The chief point here is that calcium is the base which, combined with oxygen in the proportions of 40 parts by weight of calcium to 16 parts by weight of oxygen, gives a compound calcium oxid (CaO) commonly known as caustic lime. Further, that this calcium oxid (CaO) combines with water (H_2O) in the proportion of 56 parts by weight of calcium oxid to 18 parts by weight of water to form calcium hydroxid (CaO, H_2O equal to Ca $(OH)_2$) or

TABLE XXXII.—Showing average results of CHEMICAL ANALYSES expressed in percentages the of the elements potassium, sodium, calcium, magnesium, iron, aluminum, phosphorus, sulfur and carbon, instead of their oxids. (Compare Table III).

	No Analyses	Insoluble matter and soluble silica	SOLUBLE AND VOLATILE MATTER.														Humus (carbon ×1.727)	Total nitrogen
			Potassium K	Sodium Na	Calcium Ca	Magnesium Mg	Iron Fe	Aluminum Al	Phosphorus P	Sulfur S	Oxygen in oxids O	*Carbon C	Moisture H_2O	Combined water H_2O	Other volatile matter	Total		
SOIL—1st six inches																		
Wooster (East Farm) ...	16	88.73	.179	.289	.200	.235	1.867	1 479	.039	.016	2.561	1.037	.841	974	1 558	100 005	1 791	.096
Wooster (South Farm) ..	5	87 53	.260	.178	.150	.235	1 888	1.702	.069	.012	2 757	1 240	.842	1.121	1 727	99 71	2 152	.091
Wooster, average.	21	88 44	.198	.193	.185	235	1.874	1 526	.046	.012	2 575	1 085	.841	1.005	1 589	99.801	1 874	.093
Strongsville	13	83·58	.170	.215	.157	.277	2.266	1.734	055	.020	2 968	2 081	1 592	1 142	3 495	99 752	3.534	.187
Columbus	8	83 44	.468	.539	.400	.374	2.385	2.572	.062	.036	4.140	1.852	1 11	1.693	1 205	100 226	3 106	.249
Neapolis (yellow sand) ..	2	93 21	.044	.044	.135	.072	.692	.525	.054	.012	.980	1.285	.945	.345	1.375	99 718	2.219	.091
Neapolis (black sand) .	2	99 37	.042	.066	.214	.078	.468	.424	.059	.012	.842	2.722	1.115	.279	3.058	99 749	4.653	.120
Germantown	1	90 55	.118	.155	.078	.187	1.175	1 681	.045	.012	2 303	.802	1.045	1.107	.746	100 009	1 385	.090
Carpenter	2	85 73	.155	081	.128	.181	1.909	2.119	.049	.012	3 005	1.216	1.116	1.393	3.165	100.259	2.109	.138
SUBSOIL—2nd six inches.																		
Wooster (East Farm)....	16	87.87	.294	.282	.193	.223	2 322	1.808	.043	.016	3.043	.503	.950	1.190	1.467	100.114	.869	.064
Wooster (South Farm) ..	5	87 67	.220	.208	.143	.272	2.281	1.888	.063	.012	3.102	.503	.844	1 243	1.430	99.879	.869	.060
Wooster, average........	21	87 85	.228	.252	.179	.235	2 309	1 835	.048	.016	3.057	.503	.923	1.208	1.465	100 079	.869	.061
Strongsville.	13	83.80	.179	.215	.129	.272	3 302	2.180	.040	.012	3 757	.629	1.615	1.435	2.241	99 806	1.086	.174
Columbus.	8	83.87	.464	.579	.493	.374	2 540	2.259	.065	.040	3 975	1.750	1.22	1.487	1.19	100.309	3.012	.135
Neapolis (yellow sand)..	2	94 31	.054	.052	.100	.078	.574	1.044	.050	.008	1.370	.579	.805	.688	.218	99 930	.999	.037
Neapolis (black sand) ..	2	93.18	.050	.067	.172	.084	.784	.710	.048	.004	1.191	1.542	.950	.467	.821	100.020	2 673	.113
Germantown........	1	89 20	.174	.171	.093	.223	1.581	1 957	.050	.012	2.774	.860	1 180	1.288	.532	100.102	1.485	.090
Carpenter..............	2	81.75	.212	029	.107	.223	2.428	2.583	.037	.012	3.658	.468	1.208	1.700	2.204	99.678	.803	.070

the slaked lime of popular knowledge. The composition of this compound will not be different when in the dry state, whether derived from the application of water or steam to the caustic lime directly or formed by the slow process of water absorption from the atmosphere. In either case the final resultant product is calcium hydroxid. So for the other elements and compounds which are designated in these two tables of results of chemical analyses. The combinations of the elements with oxygen are all in definite proportions. The small figures below and to the right of the abbreviation of the element of whatever nature, as in the case of K_2O, Na_2O, F_2O_3, P_2O_5, etc., indicate the number of atoms of each element entering into combination. In the case where no sub-number is employed, as in CaO, MgO, a single atom of the element is understood to be in combination. Some of the factors derived from these atomic proportions are included in the table of units and factors at the end of this bulletin. It will be observed that unlike in Table III, in Table XXXII an effort has been made to separate the loss of the soil samples upon drying and igniting into absorbed "moisture," "combined water" and "other volatile matter"; also that the *carbon percentage here first introduced indicates material burned out upon ignition and in the other tables is included under the somewhat indefinite term of "organic matter."

THESE SOILS ALL HIGH IN INSOLUBLE MATTER.

Any one studying the chemical composition of these soils will be impressed by the high percentages of insoluble matter, ranging as they do from 83½ per cent, approximately, at Strongsville and Columbus to 93.2 per cent in the yellow sand of Neapolis. The insoluble matter thus included represents the substances insoluble in the acid of the strength employed to prepare the soil solutions, together with a small quantity of silica passing into the solution and rendered insoluble by subsequent evaporation. This insoluble mass represents the silica (true sand and quartz of the soil) and the insoluble silicates which may be present in the soil mass.

In the diagrams, Tables XXX and XXXI, it was found impracticable to include the insoluble matter and to represent the proportions of the various soluble constituents of the soil in any-

*Through the kindness of Dr. C. G. Hopkins, chemist of the Illinois Agricultural Experiment Station, Mr. Ames was able to take advantage of the opportunities afforded in their laboratory to determine the percentage of carbon in composite samples of various soils and subsoils. This was done by the determination of carbon dioxid (CO_2) using the Parr Bomb Calorimeter. The humus percentages added to Table XXXII are, as shown, derived from the carbon percentage by multiplication, using the factor given.

thing like a striking manner. The same reason applies and led to the exclusion of the percentages of iron oxid and alumina from these diagrams. The tabulations, however, are sufficiently obvious without the diagrammatic repetition. It has already been suggested in an earlier part of this bulletin, pages 85-86, that a well marked similiarity is observed in the mechanical constituents of the Wayne silt loam, the Cuyahoga silt, the Germantown silt and the Meigs silt clay (soils of Wooster, Strongsville, Germantown and Carpenter); this similarity extends in like manner to the insoluble matter of the chemical analyses. It will be borne in mind that we are discussing these particular silt soils under investigation. The high percentages of insoluble matter are parallel with moderate, or low percentages of mechanical clay and alumina. (See Tables II and III.) When we contrast the insoluble matter found in these soils with that of the more strictly limestone clay of the Kentucky Experiment Station farm (see Table XXXIII) we discover that therein only 76.87 per cent of insoluble matter occurs in the one

TABLE XXXIII.—Showing variation between soils of Kentucky Experiment Station and those heretofore considered in the amounts of insoluble matter.

	*Kentucky soil—Blue Grass		Wayne silt loam	Cuyahoga silt	Olentangy silt loam	Germantown silt	Meigs silt clay
	Sample No. 2	Sample No. 3	(average)	(average)	(average)	(average)	(average)
Insoluble matter	76.874	80.520	88.44	83 58	83 44	90 55	85 73
Potash (K_2O)	.405	.422	.239	.205	.564	.142	.187
Soda (Na_2O)	(.165)	(.186)	.26	.29	74	.21	11
Lime (CaO)	.460	.379	.26	.22	56	.11	.18
Magnesia (MgO)	.425	.381	.39	.46	.62	31	.30
Ferric oxid (Fe_2O_3)	3.504	3.251	2.68	3 24	3 41	1 68	2.73
Alumina (Al_2O_3)	6.613	6.191	2.88	3.27	4.85	3 17	3 99
Phosphorus pentoxid (P_2O_5)	.496	.418	.105	.127	142	102	112
Sulfur trioxid (SO_3)	......	......	.03	.05	09	.03	03
Water and organic matter	......	......	4.52	8 31	5 86	3 70	6 89
Total	......	......	99.81	99 75	100.27	100 00	100 26
Total nitrogen	.276	.190	.093	187	249	090	.138

*SAMPLE NO. 2—Virgin soil taken to the depth of about 6 inches from a woodland bluegrass pasture adjoining the experimental field of the Kentucky Station. Present forest growth ash, elm, honey locust, coffee-bean, hickory, black walnut and sugar maple.

*SAMPLE NO. 3—Cultivated soil from an unfertilized plot in the experimental field of the Kentucky Station, taken also to the depth of about 6 inches. This soil has been in cultivation many years, but is believed never to have received any fertilizer

Peter, A. M. Division Chemistry U. S. D. A. Bull. 43:29-41.

sample and 80.52 per cent in the other after 36 hours digestion compared with 10 hours digestion in our samples. The same holds true in clay soils elsewhere. This is mentioned in passing merely to call attention to this conspicuous component of the soil. A more detailed discussion of the elements which are soluble will be given upon a subsequent page. It will also be noted that, with the exception of the Columbus soil, the actual percentages of potassium are low and the same applies in general to the percentages of lime or calcium and of phosphorus. The total nitrogen is much more variable.

THE WOOSTER SOIL STRONGLY ACID.

It is necessary to point out the strongly acid reaction of the Station farm soil, Wooster. The same applies to the soil at Strongsville and doubtless to some of the others where the test has been less complete. This soil acidity is shown qualitatively by the power to redden moistened blue litmus paper. Quantitive methods are being worked out by investigators. Results in this line may be expected later.

One of the sources of soil acidity is fond in the tendency of the soil bacteria, acting upon the remains of plants, to produce various kinds of acids in the soil, when this decay goes forward in the presence of insufficient amounts of lime and magnesium bases to combine with the acids. These acids are often referred to under the name of humus acids. It may be inferred with reserve that the increase in the soil humus by the most advanced methods of culture increases at a like rate the risk of organic soil acidity, unless the soil content in the way of calcium and magnesium compounds furnish the natural check. The possible injury from mineral acids is in mind. The action of various determined species of soil bacteria in the production of certain acids has been investigated by Chester* who draws the following conclusion:

"Most of the soil bacteria so far studied produce considerable amounts of acid in media containing carbohydrates. These acids include acetic, formic, propionic, butyric and lactic acids.

"All soils containing larger or smaller quantities of vegetable matter are liberally supplied with carbohydrates in one form or another, hence all soils have a tendency to become acid as a result of the development of soil microbes."

The attainment of the highest cultural results in our soils will thus be limited by the development of soil acids or be interwoven in this manner with the available amounts of calcium and magnesium carbonates capable of correcting the condition: these carbonates may be found existing in the soil or be added in practice to attain the balance. Soils high in insoluble matter are rarely high

*Chester F. D. Report of Delaware College Agricultural Experiment Station, (1899). 11:84

in the basic compounds which neutralize acidity. The writers would point to high lime content in the black soil at Neapolis and elsewhere as indicating the power of this organic matter to retain available lime compounds. Soil acidity is, further, poisonous, or toxic to a very large number of cultivated plants. Perhaps we do not need to except any plants cultivated in our state from the list of those injured by an excess of acid, while at the same time a low acidity favors the growth of several. The question has been investigated by Wheeler[1] and his associates, and by others[2] likewise.

Soil acidity and the effect of lime are being studied at this Station. Applications of lime have been found to favor good clover stands, and to increase the possible clover yield.[3] It is not quite clear that the organisms most largely concerned in the symbiotic or mutual existence in the root nodules of clovers and other legumes, by which atmospheric nitrogen is appropriated by these crops, is actually favored by an alkaline reaction in laboratory cultures. Most investigators have found a slightly acid medium most satisfactory. But as field experimentation shows conclusively that this action is increased in acid soils by applications of lime we must look for the effect either upon the host or upon the microbes. Whether this is to be attributed alone to overcoming the toxic or poisonous influence of the soil acids upon the clover plant, or whether it is due to this and the maintenance of conditions favorable to the co-operation of the soil bacteria, or to the increase of available lime or other elements for plant food as well, is not clear to the writers. Wheeler[4] states that "the utilization of atmospheric nitrogen by certain of the leguminous plants (notably the clovers) particularly upon sour soils, is facilitated by the application of lime." The matter of lime application is introduced here simply because it illustrates what must follow in practice with acid soils, which are likely to be soils deficient in lime. Where soils naturally contain an adequate supply of lime no such necessity arises for this application. This has been touched upon by Veitch[*] who makes the following observations:

"Broadly speaking, no more striking proof of the importance of maintaining an alkaline reaction of the soil is needed than is furnished by those soils which have become famous for their per-

[1]Wheeler, Report of Rhode Island Agr. Exp. Sta., 1893: 206; 1895: 193; 1896: 242-243; 1900: 293-327; Farmers' Bulletin No. 77, U. S. D. A.; 1898.
[2]Patterson, H. J., Maryland Exp. Sta., Bulletin 66.
[3]Thorne, C. E. Ohio Exp't. Station, Bulletin 141 (1903): 79-80.
[4]Wheeler, Farmers' Bulletin No. 77, U. S. D. A., p. 6, (1898.)

*Veitch, F. P. Comparison of methods for the estimation of soil acidity. Journal Am. Chemical Society, 26; (1904) pp. 637-638 and following.

sistent fertility under exhaustive cultivation. The loess soil "regur" of India, "Tschernoseum" of Russia, chalk of England, basalt of the far northwest, prairie of the middle west, "bluegrass" of Kentucky and Tennessee, and the limestone valleys of the east—are soils which are recognized as the most fertile in their respective localities, and have maintained their pre-eminence in fertility, in some cases for thousands of years. These soils are all alkaline in reaction. The history of liming furnishes more general evidence upon the value of an alkaline reaction of the soil as one of the chief economic factors in crop production."

One of the authors has determined the soil acidity in various parts of a meadow seeded to timothy and clover upon the Station farm, Wooster. Where the clover catch was satisfactory the amount of acidity was found to be very small; but in the spots where clover was absent the acidity in all instances was found to be very high and increased with the depth.

RATIO OF THE ELEMENTS FOUND IN THE SOIL.

The ratios of potassium to the nitrogen, phosphorus, calcium and magnesium of the various soil samples are shown in Table XXXIV, together with the ratios found in plant ashes therewith appended. The ratios are also compared with those found in the Kentucky soils before referred to. A little inspection will disclose the wide range in the ratios of potassium to these various elements in the soils under consideration. The deficiency of the soils at Wooster, Strongsville, Columbus, Germantown and Carpenter in phosphorus seems to be inferentially shown from this table. The deficiency of the Neapolis soil in potassium is likewise apparent, while the relative deficiency of the soils at Wooster, Strongsville, Germantown and Carpenter in calcium is at the same time obvious. The large quantities of the bases, potassium and calcium, in the Columbus soil does not stand forth in the ratio, but is apparent in the table of percentages. Attention is drawn to these ratios by reason of their bearing upon the question of balanced rations for plants. While in animal feeding the proportion of the various substances desirable in a food have been worked out, much seems yet to be desired with respect to our knowledge of ratios of the elements in relation to the food of plants. The selective powers of plants may still further introduce variation in the ratios offered in the soil.

The possible use of larger amounts of calcium by clovers is indicated by the ash analyses, which are averages of results obtained at the Massachusetts Experiment Station. Two analyses there of the ashes of the soy bean give double as much calcium as potassium and a single one of the cow pea gives more than double as much calcium. The soil qualities in any case will be determined by the available character of the plant food found in the soil. A detailed discussion of a problem of this character can only be followed in connection with extended experiments to determine what ratios are most favorable.

TABLE XXXIV.—Showing the ratios of the potassium of the soils studied to the nitrogen, phosphorus, calcium and magnesium found therein; also the same in the Kentucky soil samples and the ratios of potassium to the other ash constituents in the ashes of certain farm products.

	Potassium		INDICATED RATIOS POTASSIUM TO			
			Nitrogen	Phosphorus	Calcium	Magnesium
SOIL—First six inches						
Wayne silt loam (Wooster East Farm)	1	:	.536	.217	1 117	1.313
" " " " South "	1	:	.350	.265	.377	.904
" " " " average	1	:	.469	.232	.934	1.187
Cuyahoga silt (Strongsville)	1	:	1 100	.324	923	1 629
Olentangy silt loam (Columbus)	1	:	532	.132	.854	.798
Neapolis (yellow sand)	1	:	2 068	1 227	3 068	1 636
" (black sand)	1	:	2.857	1 405	5.095	1 854
Germantown silt (Germantown)	1	:	.762	.381	.661	1.585
Meigs silt clay (Carpenter)	1	:	.890	.316	.825	1.168
Kentucky soil (No. 2)	1	:	.821	.642	.976	.762
" " (No. 3)	1	:	.543	.520	772	.654
SUBSOIL—Second six inches						
Wayne silt loam (Wooster East Farm)	1	:	.313	.211	.942	1 093
" " " " South "	1	:	.273	.286	.650	1 236
" " " " average	1	:	.293	.230	.860	1.129
Cuyahoga silt (Strongsvile)	1	:	.972	.223	720	1 519
Olentangy silt loam (Columbus)	1	:	.293	.140	1 064	.806
Neapolis (yellow sand)	1	:	.685	.926	1 852	1.444
Neapolis, (black sand)	1	:	2.260	960	3.440	1.680
Germantown silt (Germantown)	1	:	.512	.287	.534	1 276
Meigs silt clay (Carpenter)	1	:	.330	.330	.505	1.053
IN PLANT ASHES						
Clover group (average)	1	:	......	.161	1.100	.198
Grain straws and corn stover	1	:	......	.848	.959	.355
Cereal grains	1	:	......	.086	.372	.163

CALCIUM-MAGNESIUM RATIOS IN RELATION TO PLANT GROWTH.

While calcium and magnesium are both essential to plant growth, and the latter especially to seed maturity, magnesium in excess is poisonous. The toxic character has been studied and the conclusions set forth in the paper named below.

Loew and May* have presented a discussion of "the liming of soils from a physological standpoint" and "an experimental study of the relation of lime and magnesia to plant growth." They have discussed this matter at considerable length and have presented experimental data upon the subject. Plants have been grown under control of food conditions; the toxic character of magnesium compounds is also insisted upon when occuring in excess. In this presentation, however, the matter has been separated entirely from that of acid soils and is here so considered. The conclusion is reached that an excess of calcium over magnesium is desirable; for the oxids of the elements upon foliage plants, the most favorable ratio is placed at actual weight 7 to 4, (for the elements 25 to 12.) Upon cereals the ratio is placed at 1 to 1 for the oxids.†

It will be observed from the next table, XXXV, that in some of the soils where a large number of samples have been analyzed this proportion is almost reversed, and is quite reversed at Germantown by the results of the single analysis made. Leaving out of consideration the question of correcting acidity, such ratios may be corrected by application of gypsum—calcium sulfate. There are indications that ground calcareous limestone—calcium carbonate with little magnesium carbonate—is a much more beneficial substance to use on acid soils like those under discussion. Caustic lime, either calcareous or dolomitic, may be rightly preferred to gypsum, because by its use the ratio may be corrected and the soil acidity overcome. Gypsum is a neutral compound and will not correct acidity.

In the calculations of the amounts of calcium and magnesium per acre the specific gravities, or weight of soil per acre, given in the table of factors at the end of the bulletin, have been employed. In computing the applications to be made for the correction of the ratio of calcium and magnesium the raw gypsum, or hydrated calcium sulfate, has been employed; it contains about 23 per cent of

*I. The liming of soils from a physiological standpoint. II. The relation of lime and magnesia to plant growth. Bul. 1, Bureau of Plant Industry, U. S. D. A., 1901.

†See also Bull. Coll. Agric. Imp. University, Tokyo. 4: No. 4 (1901) and 6: 97 (1904).

calcium*, 32.3 per cent CaO, and very little magnesium. Since the best calcareous limestones† contain about 85 per cent of calcium carbonate and 13 per cent of magnesium carbonate and an excess of calcium carbonate above magnesium carbonate amounting to 72 per cent, this latter calcium carbonate or 51.5 per cent calcium

*TABLE XXXV.—Showing amounts of calcium and magnesium in the soils studied, together with their ratios and the application of land plaster required to make calcium and magnesium equal or a ratio of 1:1.

	No. of analyses	Calcium Ca	Magnesium Mg	Ratio of calcium to magnesium	Amount calcium per acre lbs.	Amount magnesium per acre lbs.	Excess Magnesium over calcium per acre lbs.	Weight land plaster to make calcium equal to magnesium per acre lbs.*
SOIL—1st six inches								
Wooster, (East Farm)...	16	.200	.235	1: 1.175	3400	3995	595	2587
Wooster, (South Farm)..	5	.150	.235	1: 1.566	2550	3995	1445	6283
Wooster, average	21	.185	.235	1: 1.270	3145	3995	850	3696
Strongsville.............	13	.157	.277	1: 1 764	2669	4709	2040	8870
Columbus	8	.400	.374	1: .935	6800	6358	......	......
Neapolis (yellow sand)	2	.135	.072	1: .523	2295	1224	......	......
Neapolis (black sand) ...	2	.214	.078	1: .364	3638	1326	......	......
Germantown	1	.078	.187	1: 2.397	1326	3179	1853	8057
Carpenter......	2	.128	.181	1: 1.414	2176	3077	901	3917
Kentucky No. 2.........	....	.328	.256	1: .780	5576	4352	......	.....
Kentucky No. 3.........	....	.270	.229	1: .848	4590	3893	......	......
SUBSOIL—2d six inches								
Wooster—(East Farm) ..	16	.193	.223	1: 1.155	3067	4237	570	2478
Wooster—(South Farm).	5	.143	.272	1: 1 902	2717	5168	2451	10657
Wooster, average........	21	.179	.235	1: 1.313	3101	4165	1064	4626
Strongsville	13	.129	.272	1: 2 109	2451	5168	2717	11813
Columbus	8	473	.374	1: 791	8987	7106	......	......
Neapolis (yellow sand) ..	2	.100	.078	1: .780	1900	1482	......	.....
Neapolis (black sand)...	2	.172	.084	1: .423	3268	1596	......	.....
Germantown	1	.093	.223	1: 2 333	1767	4237	2470	10739
Carpenter..............	2	107	.223	1: 2 084	2033	4237	2204	9583

*For best grades of calcareous limes only 4/9 this amount will be required.

is the amount that will be available for ratio correction under the assumption made. If dealing with such a grade of lime, we may count on 85 per cent lime (CaO) and only 11 per cent magnesia (MgO) with an approximate doubling of the percentage of insoluble matter found in the stone. The calculation is easily made. Such

*Geological Survey of Ohio VI: 700-701.
†Bul. of O. Exp. Sta. No. 127 :221-213.

lime contains 2.24 times, or $^9/_4$ times as much calcium as the land plaster and one needs only to use $^4/_9$ as much in the application to be made. It is doubtful whether it will ordinarily be profitable to make a single application of more than 2000 to 3000 pounds of ground stone or lime per acre. The dolomitic or magnesian limestones contain about 39 per cent calcium and 24 per cent magnesium, these limes having about 55 per cent calcium oxid and 40 per cent magnesium oxid. This gives only a very small excess of calcium above magnesium and the applications made necessary to correct a ratio deficient in calcium by use of these materials, from a practical standpoint, are excessive and unnecessarily expensive.

CORRELATION OF THE RESULTS OF CHEMICAL AND MECHANICAL ANALYSES.

TABLE XXXVI.—Chemical composition of the mechanical sediments, silt, fine silt and clay in the first twelve inches of soils at Wooster, Strongsville, Columbus and Carpenter.

	Insoluble matter and soluble silica	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Ferric oxid Fe_2O_3	Alumina Al_2O_3	Phosphorus pentoxid P_2O_5	Sulfur trioxid SO_3	Volatile matter	Total
Wooster silt (.05-.01 mm)	95 719	.297	.287	.126	.204	1.389	1.714	033	.025	.151	99.945
" fine silt (.01-005 mm)..	82 773	.571	.319	.249	.635	5.189	7.683	161	.034	2 497	100.137
" clay (.005-.0001 mm).	60.751	.841	.897	.676	1 209	9.202	13.821	.300	575	11.629	99.895
Strongsville silt (.05-.01 mm) ..	95.718	.278	333	.127	.237	1 393	1 716	.041	023	.133	100.012
" fine silt (.01-.005 mm)	82.569	.802	.340	.287	.625	4.567	8 101	.116	.062	2 511	99 930
Strongsville clay (.005-.0001mm	59.226	1.263	.775	580	1.283	9.385	14.295	.124	.392	12 777	100.100
Columbus silt (.05-.01 mm)....	96.011	.314	.312	.173	.227	1.249	1 728	.049	.016	.140	100.222
" fine silt (.01-.005 mm).	83.237	.888	.309	.502	.636	4.879	7.334	.270	.085	1 761	99 901
" clay (.005-.0001 mm) .	62 127	2.787	3.536	1.628	2.286	9 618	17.290	.666	.502	*....	100.440
Carpenter silt (.05-.01 mm	96 015	.212	.232	.096	.159	.929	1.977	.035	.047	.132	99 834
" fine silt (.01-.005 mm)	85.096	.361	.237	.180	.499	3 626	6.664	.102	.073	2 811	99.673

*Sample of Columbus clay ignited before analysis.

It is necessary to study the correlations existing between the results of the chemical and mechanical analyses made of these various soils of the type heretofore set forth. The next correlations are difficult to determine and for this reason one approaches the subject with hesitancy. Nevertheless, such correlations must exist if our knowledge be sufficient. If one compare in Tables II and III the total sand of the mechanical analyses with the insoluble matter of the chemical it will be apparent that the grains of sand are very largely insoluble from a chemical point of view. The silts are also high in insoluble matter, although the insoluble matter is less in the mechanical clay; but in this the percentage likewise expresses a considerable amount of soluble silica. The material base or matrix, as seen in mechanical analyses of our soils, must be very largely composed of silicon dioxid or silica, although some insoluble silicates which are not finely comminuted may be found in these sediments. The amount of plant food contained in the various mechanical sediments may vary inversely as the size of the particles and therefore inversely as the amount of insoluble matter. To determine the chemical composition and therefore the amount of plant food in the finer mechanical sediments, analyses have been made of the grades of silt and clay from Wooster, Strongsville, Columbus and Carpenter, in so far as the samples of soil would permit. These are set forth in Table XXXVI.

The increase of the percentages of all the important elements with the fineness of the sediment is especially marked and need not be fully restated. These analyses support the contention that the clay of the soil is very important as a carrier of plant food. Similar analyses of mechanical sediments have been made by Loughridge[1] on a Mississippi soil. The results obtained by him have been included by Wiley[2] and are also herein included. It will be observed that the finest sediment included by Loughride is less

[1]Proceedings American Association for Advancement of Science, 22:80.

The distribution of the soil ingredients in the sediments obtained in silt analysis.

Hydraulic value	Clay		<0.25 mm		0.25 mm		0.5 mm		1.0 mm		Other sedi-ments	Total in sedi-ments	Orig-inal soli
Per cent in soil	21.64		23.56		12 54		13.67		13 11				
	A	B	A	B	A	B	A	B	A	B			
Insoluble residue ..	15 96	4 35	73.17	17.29	87.96	11 03	94.13	12 72	96.52	12 74	13.76	71.89	70 53
Soluble silica	33 10	7 17	9.95	2 34	4.27	0 53	2.35	0.32	......		......	10 36	12 30
Potash	1 47	0 32	0 53	0.12	0 29	0 04	0 12	0 01	......		.....	0 49	0 63
Soda	1.70		0 24	0.06	0 28	0 04	0 21	0 02	......		.....	0 12	0 09
Lime	0 09	0 03	0 13	0 03	0 18	0 02	0 09	0 01	......		.....	0.09	0 27
Magnesia	1 33	0 29	0 46	0 11	0 26	0 03	0 10	0 01	......		.....	0 44	0 45
Manganese.......	0.30	0 06	0 00	0 00	0 00	0 00	0.00	0 00	......	0.36	.....	0 06	0 06
Ferric oxid	18 76	4 06	4 76	1 11	2 34	0 29	1 03	0 14	......		......	5.60	5.11
Alumina	18.19	3 97	4 32	1 04	2 64	0 33	1.21	0 17	......		......	5.51	8.09
Phosphoric acid ...	0 18	0.04	0 11	0 02	0 03	0 00	0 02	0 00	......		......	0 06	0 21
Sulfuric acid	0 06	0 01	0 02	0.01	0 03	0 00	0 03	0 00	......		......	0 02	0.02
Volatile matter ...	9.00	1 33	5.61	1.43	1 72	0 23	0 92	0 29	...		....	3.64	3.14
Total	100 14	21.64	99.30	23.56	100.00	12.54	100 21	13 67	.....	13 10	....	98 28	100.63
Total soluble matter...	75 18	.....	20 52	.....	10 32	.....	5.16	.	.	......	..	..	.
Total soluble bases	41.84	......	10 44	.....	5 99	.....	2.75	..	......	....	......	.	....
Soluble silica in crude substance	0 38	0 01	.....	.....	......	......	....	.....	..	.. .	. ...	...	0.19

A. Calculated on the amount of sediment B Calculated on the amount of soil.

Loughridge, Proceedings A. A. A. S. 22:81.

[2]Principles and Practice of Agricultural Analysis: I: 247.

than .25 of a mm. and therefore is not strictly comparable to the determinations in the table wherein the coarse sediment has a diameter of .05 mm.

When it comes to the correlation and the percentages of clay as determined by the mechanical analyses, and the percentages of clay as indicated by the aluminum oxid of the chemical analyses, the following table, No. XXXVII, will bear evidence. We have

TABLE XXXVII.—Showing comparison of soluble clay content indicated by chemical analysis and that found by the method of mechanical analysis.

	Actual Al_2O_3	Calculated clay $Al_2O_3 \times 2.51256$	Mechanical clay
SOIL—First six inches			
Wayne silt loam (Wooster East Farm)	2.79	7.009	4.60
" " " " South "	3.21	8.065	4.26
" " " " average	2.88	7.236	4.54
Cuyahoga silt (Strongsville)	3 27	8 216	7.18
Olentangy silt loam (Columbus)	4 85	2.185	6.12
Neapolis (yellow sand)	.99	2.487	2.46
Neapolis (black sand)	.80	2.010	1.22
Germantown silt (Germantown)	3.17	7.964	8.89
Meigs silt clay (Carpenter)	3 99	10 025	9.71
Kentucky soil (No. 2)	6.613	16.615	....
" " (No. 3)	6.191	15.555	....
SUBSOIL—Second six inches			
Wayne silt loam (Wooster East Farm	3 41	8 567	6.57
" " " " South "	3 56	8.944	7.38
" " " " average	3 46	8.393	6.71
Cuyahoga silt (Strongsville)	4.11	10 326	15.61
Olentangy silt loam (Columbus)	4 26	10.703	7.42
Neapolis (yellow sand)	1 97	4.949	2.39
Neapolis (black sand)	1 34	3.366	2.07
Germantown silt (Germantown)	3 69	9 271	14.58
Meigs silt clay (Carpenter)	4.87	12.237	16.01
FIRST TWELVE INCHES			
Wayne silt loam (Wooster East Farm)	3.10	7.788	5.585
" " " " South "	3 385	8 5045	5.82
" " " " average	3.17	7.9645	5.63
Cuyahoga silt (Strongsville)	3 69	9.271	11.395
Olentangy silt loam (Columbus)	4 48	11.444	6.77
Neapolis (yellow sand)	1.48	3.718	2 425
Neapolis (black sand)	1 07	2.688	1.645
Germantown silt (Germantown)	3.43	8.6175	11.735
Meigs silt clay (Carpenter)	4.43	11.131	12 86

frequently re-checked our determinations of mechanical clay because they seemed to us lower than we might reasonably expect; therefore as a check we have taken the chemical composition of pure clay[1] (Al_2O_3 $2SiO_2+2H_2O$) and have computed the clay indicated by the chemical analyses from the amounts of alumina (Al_2O_3) found. The insoluble nature of pure kaolin or clay introduces here some doubtful factors. These percentages are set forth fully in the table, together with the percentages found in the soil at the Kentucky Station already mentioned. For the first six inches the results show unsatisfactory divergence in the Wayne silt loam and a much closer agreement in all the other soils except, perhaps, in that of Columbus, where it may be that the fusion of the soil samples with alkali has given higher alumina percentages than might be expected by the method of digestion employed in the other analyses. The Cuyahoga silt of Strongsville shows higher percentages of mechanical clay than of calculated clay in the subsoil as also in the first 12 inches; the same applies to the Germantown silt and the Meigs silt clay.

BIOLOGICAL SOIL FACTORS.

The previous discussions will prepare us to appreciate the biological or living factors in crop production. Soils vary in their native growths which we may assume are more or less self adapted to the conditions therein existing. This soil carries oak and hickory; that, beech and sugar trees. These are biological facts that the farmer notes and profits by, in the choice of crop staples. Soil exhaustion, soil drainage and the additions made by various applications introduce changes in the soil conditions. It may be that in some earlier discussions strained emphasis has been laid upon soil exhaustion. The changes in the soil other than by exhaustion of plant food have been undervalued. By manuring, either by the use of stable manure or by green manuring, the increase of vegetable matter containing the various carbohydrates, (such as starch, fiber, etc.,) leads to the production of various acids through the action of the soil bacteria upon these substances. The biological possibilities of the soil are thus modified by the reactions going forward in it. Toxic conditions are set up and overshadow the ordinary qualities of the soil. Possibly the crop suffers and a change of crop staples becomes necessary under certain conditions. But if the soil possess its own corrective for this acidity then no change is so imperatively demanded in the crops or soil treatments

[1]See Ohio Geological Survey 5:646.

unless the balance of mineral plant foods for the crops grown be unsatisfactory. Thus at every step in our cultural progress we observe that the needs of the plants (crops) grown and the possibilities of the soil in relation to suppyling these needs, these favorable conditions of environment, are often not fixed but extremely variable factors. We all realize how true this may be within very brief lapses of time in relation to the water supply of the soil. Do we appreciate as a rule, the variations which may occur in the soil as a matrix or nidus? Or by what tokens are we assured of the soil balance? It is to these biological forces of crop and soil bacteria as well as the usual plant food considerations that we would appeal here.

A little further reflection will convince most persons that whether we seek to investigate the soil by one method or by another, by chemical, mechanical or experimental methods in the field, we inevitably come in the end to the consideration of the processes of the plants cultivated. These include the study of plant poisons, plant foods, plant nutrition, soil moisture relations and of the adequacy of the soil plant food. Experiments will continue to be necessary in this line for long years to come. If certain substances are poisonous or toxic to the plant, these substances must be neutralized or rendered innocuous by the necessary applications or treatments. It is not enough that plants have grown in a way; the best and therefore the most profitable production is demanded.

These correctives of the balance of biological conditions are the true end of soil investigations. The soil life, not the soil of itself, is the factor after all that demands the maximum consideration and study.

UNITS AND FACTORS EMPLOYED.

Units	Soil weights
Soil First 6 inches	*1,700,000 lbs. per acre
Subsoil—Second 6 inches	*1,900,000 " " "
Total—First 12 inches	3,600,000 " " "

*Average of five or more determinations of water-free soil weight, Wooster

FACTORS

GIVEN:—			TO FIND:	
COMMON NAME	CHEMICAL NAME	FORMULA		FACTOR
Potash	Potassium oxid	K_2O	Potassium, K	0 83033
Soda	Sodium oxid	Na_2O	Sodium, Na	0 74235
Lime (caustic)	Calcium oxid	CaO	Calcium, Ca	0 71480
Slaked Lime	Calcium hydroxid	$Ca(OH)_2$	Calcium, Ca	0.541[illegible]4
Slaked Lime	Calcium hydroxid	$Ca(OH)_2$	Water, H_2O	0 24[illegible]0[illegible]
Land Plaster	Calcium sulfate	$CaSO_4$	*Calcium, Ca	0 [illegible]451
Calcareous Limestone	Calcium carbonate+	$CaCO_3$+	*Calcium, Ca	0 4[illegible]0
Magnesia (caustic)	Magnesium oxid	MgO	Magnesium, Mg	0 [illegible]0377
Dolomitic Limestone	Magnesium oxid+	$MgCO_3$+	*Magnesium, Mg	0 [illegible]887[illegible]
Red Oxid of Iron	Ferric oxid	Fe_2O_3	Ferrum (iron) Fe	0 [illegible]99[illegible]2
Alumina	Aluminum sesquioxid	Al_2O_3	Aluminum, Al	0 5[illegible]0[illegible]
Phosphoric Acid†	Phosphorus pentoxid	P_2O_5	Phosphorus, P	0 436[illegible]2
Bone Phosphate of Lime	Calcium phosphate	$3CaO, P_2O_5$	* " P	0 19981
" " " "	" "	" "	Phos pentoxid P_2O_5	0 45762
" " " "	" "	" "	Calcium, Ca	0.387[illegible]9
Sulfuric Acid†	Sulfur trioxid	SO_3	Sulfur, S	0 40045

*It is to be understood that the factors given in these cases apply simply to the amounts of the specified carbonates, sulfates, etc , found in the material

†It is to be noted that these are not true acids, but the anhydrids or oxids from which acids are formed by combination with water.

CORRECTIONS.

Page 95; subsoil Germantown total "100 20" instead of "100 10."

Page 100; subsoil medium sand read " 5- 25 mm" instead of "5-.25 mm."

Page 100 subsoil fine sand read ".25-.1 mm" instead of ' 25-.1 mm "

Page 106; in column under 872, for total read "99 39" instead of "98 39 "

Page 106; subsoil fine sand read ".25-.1 mm" instead of "25-.1 mm."

Page 107; in column under section and plot read "Sample No " instead of "Section No "

Page 108; silt read ".05-.01 mm" instead of ".95- 01 mm "

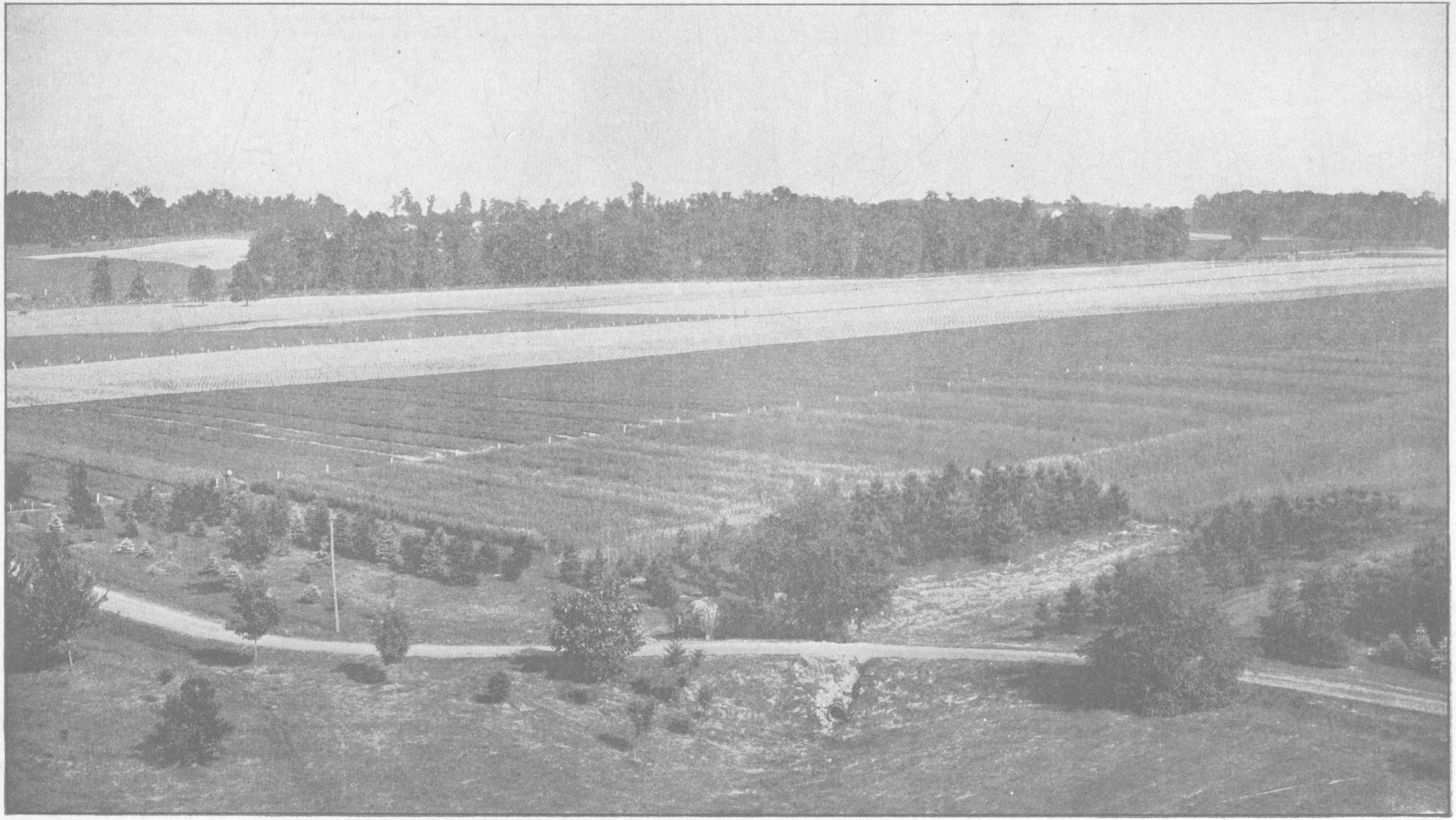
Page 108; fine silt read " 01-.005 mm" instead of ".014:005 mm "

Page 108; in column for 1 90. for total silt read "59.21" instead of "58.21."

Page 109; read "Table XIII" instead of "XII."

Page 109; subsoil, in column under 16, for alumina (Al_2O_3) read "4 52" instead of "4 18." In column under 19 for alumina (Al_2O_3) read "4 18" instead of "4 52 "

Page 110; soil under column of average for total read "99.98" instead of "99 08 "



F om a photograph by W. H. Kramer

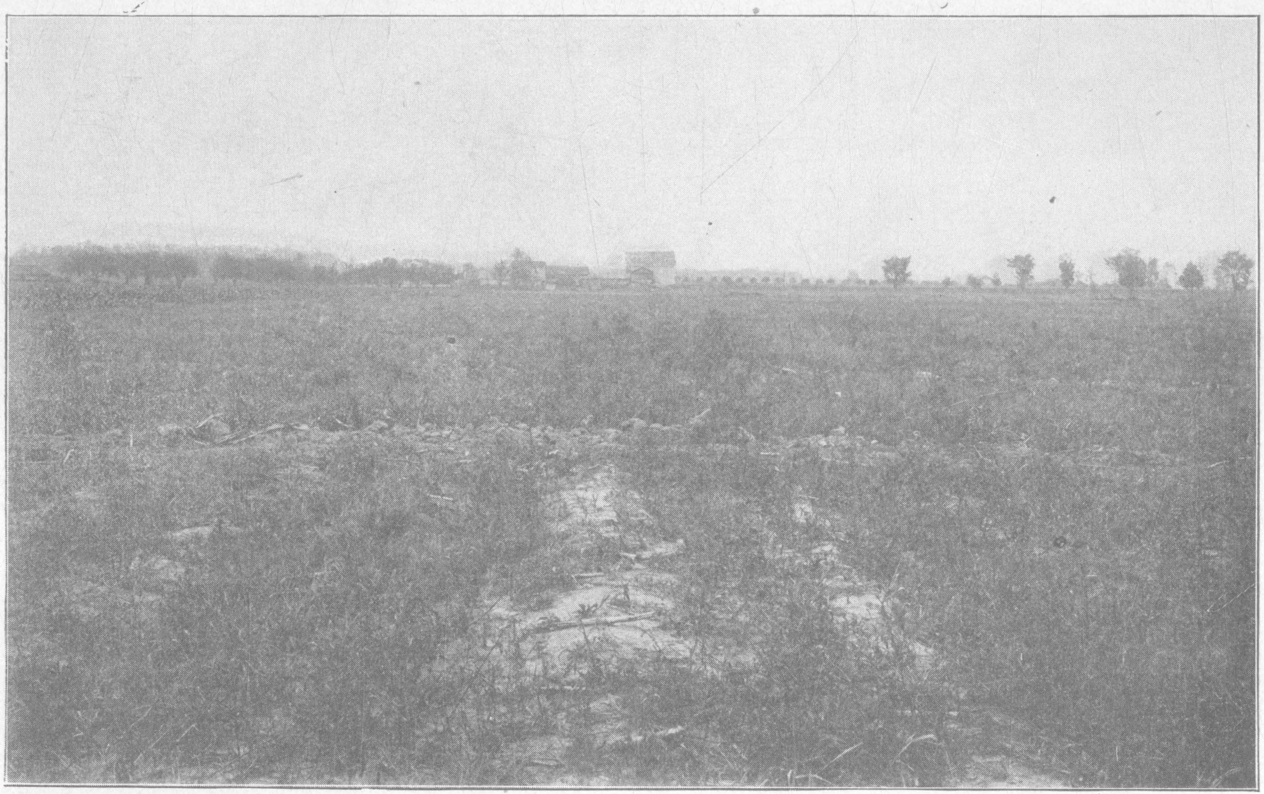
PLATE I.—View of the Station Farm, Wooster, looking southeast from the tower of the Administration Building. The foreground (West Farm) is occupied by the plots devoted to variety tests; the background on the right gives a glimpse of the South Farm and on the left of the East Farm.

From a photograph by A. D. Selby.

PLATE II—View of the Northwestern Test Farm, Strongsville, Cuyahoga county, looking north across the Pomeroy Tract—Strongsville Station in the background.

From a photograph by A. D. Selby.

PLATE III—View of the former Northwestern Test Farm, Neapolis, Fulton county, looking northeast from the crossroad.



From a photograph by A. D. Selby

PLATE IV—View of the land occuppied by the Southwestern Test Farm, Germantown, Miami county, looking north.

From a photograph by C. E. Thorne

PLATE V—View of the Southeastern Test Farm, Carpenter, Meigs county, looking toward the northeast. The upland to right is occupied by a newly planted apple orchard; the extreme foreground of slope by catalpa planting.

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